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Founded by J. A. Nieuwland, C.S.C.

Contents

New Species of Trematodes from the Gills of Illinois Fishes—*John D. Mizelle* 785

Notes on Some Parasitic Copepods and a Mite, Chiefly from Florida Fresh Water Fishes—*Justus F. Mueller* 807

The Life History of the Fan-Tailed Darter Catonotus flabellaris flabellaris (Rafinesque)—*Charles T. Lake* 816

Food Habits of Marsh Hawks in the Glaciated Prairie Region of North-Central United States—*Paul L. Errington* and *W. J. Breckenridge* 831

The Genus Carex in Kansas—*Frederick J. Hermann* 849

A Preliminary Vegetation Map of Indiana—*Robert B. Gordon* 866

A New Coral from the Olentangy Shale of Ontario—*Grace Anne Stewart* 878

Vol. 17 SEPTEMBER, 1936 No. 5

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New Species of Trematodes from the Gills of Illinois Fishes*

John D. Mizelle

This investigation began in the fall of 1933 as a general survey of the parasites of the *Centrarchidae* of Champaign County, Illinois. After two years of collecting, an attempt was made to identify the collected specimens. Due to coagulation of adherent mucus and subsequent adhesion of specimens to the inner surfaces of the vials, no Gyrodactyloidea were found in the fluid poured from containers in which they were originally placed. New material was collected and identification of parasites in a live state was begun, together with work on the problem of perfecting a suitable technique adequate for research on this group. Examination revaled several undescribed species of gill trematodes of the subfamily *Tetraonchinae,* twelve of which are treated in this publication. The problem has been restricted to the monogenetic forms from Illinois fishes.

Specific taxonomic investigations concerning *Gyrodactylidae* from American fresh-water fishes have been few. Most important are the works of Van Cleave (1921), Van Cleave and Mueller (1932), Mueller and Van Cleave (1932), Van Cleave and Mueller (1934), and Mueller (1934 and 1936). In 1934 Mueller created the genera *Urocleidus* and *Cleidodiscus* and in 1936 he created the additional genera *Onchocleidus, Tetracleidus* and *Leptocleidus*. The established genus *Ancyrocephalus* was made to include solely marine forms and was retained in only a provisional manner for fresh-water *Tetraonchinae*. Including the present descriptions twenty-eight species of *Tetraonchinae* and six of *Gyrodactylinae* have been described from American hosts. According to Mueller (1936) forty-three species of *Gyrodactylinae* and six of the *Tetraonchinae* have been described from European hosts. Although the investigations concerning the family *Gyrodactylidae* have not been extensive in America, the above information would seem to indicate that the *Tetraonchinae* are far more abundant in this country than are the *Gyrodactylinae,* whereas the converse is true in Europe.

The writer wishes to express his thanks and appreciation to Professor H. J. Van Cleave of the Department of Zoology of this University for his encouragement and valuable suggestions, to Dr. D. H. Thompson of the

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Illinois State Natural History Survey for his generous assistance and co-operation in collection and identification of host material, and to the graduate students of this department who have so willingly aided at all times in the collection of host species.

Material and Methods

Due to a lack of time for examination of a large number of fishes collected from several localities on the same date, freezing was resorted to as a means of host preservation. On examination of branchial material so treated, many of the monogenetic forms present were found free from the host tissues in containers used for examination. Further work on the efficacy of freezing as a method for the removal of ectoparasitic trematodes from gill material resulted in the discovery of an optimum time of exposure ranging anywhere between the extremes of six and twenty-four hours. In addition to the removal action, freezing also has the simultaneous effects of killing the parasites in a relaxed condition and breaking up the mucus, thereby facilitating examination and preservation. Exposure for a shorter period than that stated above fails to break up the mucus to an optimum degree while over-exposure contorts the specimens. After freezing, the fishes were thawed in tap water, the gills removed, placed in a homeopathic vial about two-thirds full of water and vigorously shaken for about fifty consecutive shakes. The liquid containing the parasites was then poured into watch glasses and alternately diluted and decanted until clear enough for examination with a binocular microscope. The parasites were collected with a capillary pipette equipped with a rubber bulb and transferred to clear water to insure further removal of mucus. Experiments have shown that this method is effective in removing ninety-two per cent of the total gill trematodes present.

For measuring, freshly killed specimens were mounted on a slide without a cover-glass, in a solution of equal parts of gylcerine and water. Each mean measurement given in this work is a calculated average derived from measurements of twenty different specimens.

For making permanent mounts the specimens were taken from the container and transferred to slides coated with Mayer's albumen. They were then placed in a finger bowl on inverted stender dishes. Alcohol was poured in the bottom of the container to a level below the top of the stender dishes, the top of the bowl was covered and the apparatus set in an incubator. It was found that exposure for a period from one to five minutes at fifty-five degrees centigrade was sufficient to coagulate the albumen and securely attach the specimens to the slide. Because of the small size and the tendency of the anchors to become entangled in debris and cuticula of other specimens it was practically impossible to treat these forms in vials during the ordinary technical processes requisite for mounting. After attachment of the specimens to the slides they were fixed in Gilson's fluid, treated with iodine for removal of mercuric salts, stained in borax-carmine and mounted in balsam.

The term haptor for the caudal attachment organ, proposed by Price

(1934), is adopted. The following terms are used as proposed by Mueller (1936): anchors, for the large hooks of the haptor; wings, for the membranous structures arising from the convex surfaces of the shafts of the anchors; bars, for the chitinous structures connecting the bases of individual members of a pair of anchors, and hooks, for the smaller marginal armature of the haptor. The term copulatory complex is used for the male copulatory apparatus composed of the cirrus and accessory piece.

The bases of the two pairs of anchors lie embedded in the substance of the haptor. In forms with the bars non-articulate with each other, the shafts curve toward and the points protrude from the dorsal and ventral surfaces of this organ. For ease of reference the two roots comprising the bases of the anchors are designated with relation to the surfaces of the haptor. The root nearest the surface of either side is thus designated the superficial root and the opposite, the deep root. In forms with the bars articulate both pairs of anchors lie on the ventral side of the haptor and while the designation of the roots is the same, the anchors and bars are designated anterior and posterior instead of ventral and dorsal as is the case when the bars are non-articulate. The hooks are numbered consecutively beginning on the ventral surface near the basal portion of the haptor and continuing posteriorly. The two dorsal hooks on each side are numbered six and seven, number six being the more posterior. Hook number five is situated nearer the ventral than the dorsal surface of the haptor and may lie between the bars or between the shafts of the ventral anchors. In forms with the two bars articulate (only in the genus *Cleidodiscus*) the arrangement of the hooks varies slightly from the normal order in that hooks six and seven are not dorsal but ventral and posterior. The most posterior hook is number seven.

Descriptions are based on living material as well as on stained and unstained mounts for each species. Sections were made of *Cleidodiscus incisor* n. sp. and *Cleidodiscus capax* n. sp. Measurements do not follow surfaces of curved structures but have been made across the arcs formed by them. For instance in the case of anchors, the length consists of a measurement from the tip of the deep root (superficial root in the case of *Cleidodiscus articularis* n. sp., *Cleidodiscus incisor* n. sp., and *Onchocleidus acuminatus* n. sp.) to the region of junction of the shaft and point of such structures. The width of the anchors is measured across the roots.

Type material of the species herein described is in the possession of the author. After completion of work of a more detailed descriptive nature, representative material will be deposited in the U. S. National Museum, Washington, D. C.

Systematics and General Morphology

Johnston and Tiegs (1922) working on the ectoparasitic trematodes of Australian hosts were the first to give comprehensive consideration to the *Gyrodactylidae*. Their review of the taxonomic categories to subfamily is in general acceptable to the present writer for classification of forms found on

North American fresh-water fishes. The following keys are quoted directly from their monograph.

Key to the Families of Gyrodactyloidea, after Johnston and Tiegs, (1922)

A. a. Glandular structures present on head ..... B
   b. Glandular structures entirely absent ..... *Monocotylidae*
B. a. Ducts from the glands concentrated into distinct "head-organs" C
   b. Ducts from the glands scattered diffusely over part of the head ..... *Calceostomidae*
C. a. Minute, very robust worms, in which the yolk system has, in addition to the ordinary transverse duct anterior to ovary, at least one posterior transverse duct which communicates with the intestinte ..... *Protogyrodactylidae*
   b. Slender worms, in which this character of the vitelline system is quite absent ..... *Gyrodactylidae*

Key to the Subfamilies of Gyrodactylidae, after Johnston and Tiegs, (1922)

A. a. Adhesive disc provided in numerous small suckers ..... *Merizocotylinae*
   b. Disc devoid of such suckers ..... B
B. a. Disc provided with a pair (dorsal and ventral) of accessory structures, consisting of concentrically arranged rows of scales or broader famellae ..... *Lepidotreminae*
   b. Disc devoid of such structures C
C. a. Disc with four large hooks ..... *Tetraonchinae*
   b. Disc with two large hooks ..... *Gyrodactylinae*

The following is a description of the general morphology of species of the genera *Cleidodiscus* Mueller, 1934, and *Onchocleidus* Mueller, 1936, as emended in the present paper.

Tetraonchinae of a general fusiform shape, body devoid of surface scales (except *Cleidodiscus incisor* n. sp.) and with internal monaxon spicules not infrequently present in the parenchyma. Haptor hexagonal or disc-like in shape, and generally set off from the body by a peduncle.* Four anchors always present, similar in shape but often noticeably different in size. Anchors differentiated into bases, which are usually bifurcate to form two roots; solid or hollow shafts; and points which project from the surface of the haptor. The shafts may be regularly recurved distally merging imperceptibly into the points, or sharply so, to form a distinct internal angle at this locus. Two bars always present connecting the bases of individual members of the two pairs of anchors. The bars may or may not be articulate with each other. Seven pairs of chitinous hooks invariably present. These structures may be solid or hollow cylindrical bodies ending distally in sickle-shaped terminations and opposable pieces or solid structures morphologically differentiated into bases, shafts, sickle-shaped terminations and opposable pieces. Two pairs of eyes present, located at about the same horizontal level, with the anterior pair invariably smaller. Each eye spot is composed of an aggregation of melanistic granules which are easily separated with pressure. A group of glandular cells exist on each side of body in region of pharynx. Head organs of varying numbers are present on the antero-lateral margins of the cephalic region.

*Due to contraction at death, the postero-lateral sides of a haptor, normally hexagonal, may be pulled together to the extent that the posterior side is practically obliterated and the structure assumes a pentagonal shape. The junction of the haptor with the body is considered one side.

Digestive system.—The mouth is located in the mid-ventral line near the level of the anterior eye spots. A short buccal canal passes posero-dorsad to enter the well developed pharynx. The short esophagus bifurcates to form two intestinal crura which traverse the lateral body regions and unite posteriorly in the region of confluency of the vitellarial bands.

Reproductive system.—The testis, regular in outline, is located in the posterior half of the body either posterior, dorsal or posterior-dorsal to the ovary. The vas deferens passes forward generally on the left side of the body, usually dilating to form a seminal vesicle immediately posterior to the cirrus base. Two prostates generally present, situated near the posterior end of the copulatory complex and emptying into the cirrus base by single individual ducts. The prostates are similar to those described by Goto (1894) for the genus *Epibdella*. The copulatory complex consists of a chitinous tubular cirrus and a solid chitinous acessory piece. These two structures exist in various shape and size relationships.

The ovary is a non-lobed organ with spatial relationships with the testis as given above. It may be larger or smaller than, or about the same size as the testis. Internally it is filled with relatively large, clear, nucleated eggs of different sizes, which are easily visible in living mounts. The size of the eggs diminishes toward the posterior portion of the ovary. The oviduct arises anteriorly and passes forward near the mid-line of the body. Vitelline ducts enter the ootype, one on each side just anterior to the ovary. The shell gland varies from a thickened portion of the oviduct to a group of well defined glandular cells encircling the cotype. The uterus is a transparent, highly contractile tube emptying ventrally in the region of the copulatory complex. Never more than one egg has been observed in the uterus at a given time. A single vagina is usually present on either of the lateral body margins, generally with a chitinous tube connecting it with the seminal receptacle which lies near the anterior end of the ovary. Vitellaria exist as individual follicles arranged in two longitudinal bands whose widths extend from the dorso-lateral to ventro-lateral body surfaces. Anteriorly these bands may or may not be confluent immediately in rear of the pharynx near their anterior limit but are always broadly confluent posteriorly on the peduncle. Encroachment of the vitellaria on the mid-body regions of old individuals may become so marked as to obscure the internal organs from view.

Excretory system.—The excretory system consists of a maze of ramifying tubules terminating in flame cells. Basically a single collecting duct occurs on each side of the body in the posterior part of the anterior body half. Anteriorly, in the region of the copulatory complex, this tube bifurcates to form two ducts, one of which passes laterally at an angle of about forty-five degrees and empties on the dorso-lateral body surface. The other member passes anteriorly and opens on the dorsal side of the body, lateral to the anterior eye spots. Posteriorly the single duct referred to above, bifurcates in the region of the ovary to form two tubes which pass posteriorly, turn mesiad in the region of confluency of the vitellarial bands, unite to form one short

tube which in turn unites with its bilateral mate of the other side to form a single duct. This short common duct opens to the dorsal body surface on the peduncle near the mid-line of the body. Especially large solenocytes are often observed in the body regions from the level of the ovary to the base of the copulatory complex. Numbers and patterns of flame cells have not been worked out for the group.

Genus **CLEIDODISCUS** Mueller, 1934, emend. 1936, Mizelle, emend. 1936.

Diagnosis.—Tetraonchinae with intestine bifurcate but confluent posteriorly. Median sagittal plane passing through testis and ovary. Vagina present on the left body margin about midway the length. Copulatory complex well developed; cirrus a simple chitinous tube opening ventrally immediately in rear of the esophageal bifurcation. Accessory piece well developed, always present and articulated with the cirrus base. Haptor distinct, disc-like or hexagonal in shape. (The junction of the haptor with the body is considered one side.) Two bars present connecting the bases of members of the two individual pairs of anchors. The bars may or may not be articulate with each other. Two pairs of eyes present, anterior pair always smaller. Fourteen hooks present, each of which is always structurally differentiated into base, shaft, sickle-shaped termination and opposable piece. A pair of hooks may lie between the bars or between the ventral anchors in the region of the shafts and points. Vitellaria strongly developed as two lateral bands composed of individual follicles. Present on the gills of fresh-water fishes. Type species, *C. robustus* Mueller, 1934.

Cleidodiscus incisor sp. nov.

Hosts.—Bluegill Sunfish *(Helioperca incisor)*, Illinois River, Havana, Ill.; Chautauqua Lake, Havana, Ill.; Horseshoe Lake, Cairo, Ill.; Lake Decatur, Decatur, Ill.; Lake Senachwine, Henry, Ill.

Relatively large, robust parasites whose surfaces often possess chitinoid scale-like structures. The parechyma of old individuals very frequently contains monaxon spicules. Length about 1.414 mm. (0.615-2.296 mm.), width at level of cephalic lobes about 0.132 mm. (0.106-0.246 mm.), greatest body width 0.216 mm. (0.121-0.410 mm.), width of peduncle at junction with haptor about 0.060 mm. (0.041-0.106 mm.). Haptor disc-like, broader than long, width about 0.111 mm. (0.092-0.148 mm.), length about 0.106 mm. (0.082-0.139 mm.). Bars non-articulate with each other. Anterior eye spots almost invariably closer together than members of the posterior pair. Anchors similar in size and shape, bases bifurcate, superficial roots about the same length as the knob-like deep roots. Anchor shafts hollow, regularly recurved without formation of an angle at junction with points. Ventral anchors slightly longer than dorsal anchors. Bases of ventral anchors not conspicuously wider than bases of dorsal anchors. Length of ventral anchors about 0.026 mm. (0.021-0.030 mm.), width about 0.012 mm. (0.010-0.017 mm.). Length of dorsal anchors about 0.024 mm. (0.019-0.027 mm.), width about 0.012 mm. (0.009-0.017 mm.). Each of the fourteen hooks present is differentiated into

base, shafts, sickle-shaped termination and opposable piece. Bases ovate and much shorter than shafts. Hooks of pair number one slightly shorter than members of the other pairs. The arrangement of the hooks is characterized of forms in this genus whose bars are non-articulate with each other. Gonads situated near the middle of the body. Testis subspherical in shape and situated posteriorly to the ovary. Vas deferens dilated to form a conspicuous seminal vesicle just posterior to the base of the cirrus. Only one prostate has been observed. It is of a bulbular shape, located posterior to the cirrus base and contains a coarsely granular yellowish fluid. Copulatory complex well developed and situated in a well developed vestibule. Cirrus a simple curved chitinous tube, accessory piece solid, blade-like and with a knob present about midway its length, which serves as a site of muscular attachment. The accessory piece is articulated to the base of the cirrus. Ovary ovate in shape and with spatial relations with testis as given above. Vagina present on the left side in the anterior half of the body, vaginal canal short, with a row of spines encircling its base at the junction with the large pyriform seminal receptacle. Uterine pore situated at the right of the copulatory complex. To-date this parasite has been taken only from the bluegill sunfish. It occurs in mixed infestations with *Onchocleidus acer* Mueller, 1936, *Onchocleidus dispar* Mueller, 1936, *Onchocleidus mucronatus* n. sp. and an undescribed species of *Cleidodiscus*. Excretory and digestive systems as described for the group. Eggs sub-spherical in shape, diameter about 0.023 mm. with a petiole at each end. Eggs laid on the gills. This form is most closely related to *C. robustus* Mueller, 1934. It differs from *C. robustus* in the following respects: larger, maximum length 2.296 mm. as opposed to 1.5 mm. Haptor disc-like instead of "somewhat rectangular." The bars have shapes different from those of *C. robustus* and the dorsal bar is a trifle shorter than the ventral bar whereas the converse is true for the other form in question. Length of ventral bar of *C. incisor* about 0.028 mm. (0.025-0.032 mm.), length of dorsal bar about 0.027 mm. (0.024-0.029 mm.). The length of the bars of *C. robustus* were not given but were figured. The anchors of *C. incisor* have characteristic shapes that are distinctly different from shapes of similar structures of its nearest relative. The anchor shafts of *C. incisor* are hollow whereas those of *C. robustus* are solid. The cirrus and accessory piece of *C. incisor* are always curved in the same direction whole those of Mueller's species are figured with these structures curved in opposite directions. A row of spines is present around the base of the vaginal tube where it makes junction with the seminal receptacle; old individuals contain internal monaxon spicules and very often the body surface possesses chitinoid scale-like structures in *C. incisor* whereas no mention is made of the presence of these structures for *C. robustus*. Figure group 7.

Cleidodiscus capax sp. nov.

Hosts.—White Crappie *(Pomoxis annularis)*, Lake Decatur, Decatur, Ill.; Illinois River, Havana, Ill.

Black Crappie *(Pomoxis sparoides)*, Lake Senachwine, Henry, Ill.; Illinois River, Havana, Ill.

Large gills parasites devoid of surface scales but often with internal monaxon spicules in the parenchyma. Length about 1.603 mm. (0.959-2.050 mm.), width at level of cephalic lobes about 0.161 mm. (0.115-0.205 mm.), greatest body width about 0.301 mm. (0.180-0.410 mm.), width of peduncle at junction with haptor about 0.096 mm. (0.082-0.107 mm.). Haptor distinct, disc-like in shape and broader than long, width about 0.158 mm. (0.115-0.180 mm.), length about 0.106 mm. (0.090-0.123 mm.). The two bars are non-articulate with each other. Anterior eye spots almost invariably farther apart than members of the posterior pair. Anchors similar in shape, bases rarely distinctly bifurcate, roots very frequently not evident as separate structures. Anchor shafts solid and regularly recurved without formation of an angle at the junction of the shafts and points. Bases of ventral anchors noticeably wider than bases of dorsal anchors. Average length of the two pairs of anchors is about the same. Length of ventral anchors about 0 032 mm. (0.026-0.038 mm.), width about 0.027 mm. (0.019-0.036 mm.), length of dorsal anchors about 0.031 mm. (0.026-0.038 mm.) width about 0.023 mm. (0.019-0.029 mm.). Each of the fourteen hooks is differentiated into base, shaft, sickle-shaped termination and opposable piece. The arrangement of the hooks is characteristic of forms in this genus whose bars are not articulated with each other. Bases ovate, members of pairs numbers one and five with more ovate bases than the remaining hooks. Hooks of pairs numbers one and five are slightly shorter than the rest of the hooks. Gonads near the mid-length of the body, testis ovate and situated posterior to the ovary. The vas deferens dilates to form a seminal vesicle just in rear of the base of the copulatory complex. Prostates two in number, larger member somewhat fusiform in shape and filled with a finely granular colorless fluid, smaller member somewhat pyriform and filled with a coarsely granular yellowish fluid. Copulatory complex well developed and located in a relatively small vestibule. Cirrus a curved chitinous tube reciprocally coiled about the accessory piece. The accessory piece consists of a curved chitinous rod, articulated to the base of the cirrus. A conspicuous knob which serves as a site of muscular attachment is present in the anterior portion of the accessory piece. The distal end of this accessory structure is grooved and serves as a guide for the cirrus. Ovary sub-spherical in shape, about two-thirds the size of the testis and situated anterior to it. Vagina present on the left body margin anterior to the junction of the first and second body halves, vaginal canal a long chitinous tube connecting the vagina with the well developed seminal receptacle. Uterine pore situated ventrally and to the right of the copulatory complex base. Excretory and digestive systems common to the group.

To-date this form is the only parasite to be recovered from the gills of the black crappie. It occurs in smaller numbers on the white crappie in mixed infestations with *Cleidodiscus longus* n. sp., *Cleidodiscus uniformis* n. sp., and *Cleidodiscus vancleavei* n. sp. In size it closely approximates that of *C. incisor* n. sp. and *C. robustus* Mueller 1934, however the anchors, bars, copulatory complex and vagina are distinctly of a different morphological nature. *Cleidodiscus capax* n. sp. occurs only on the black and white crappies whereas *C. incisor* is found on the bluegill sunfish and *C. robustus* only on the

pumpkinseed, bluegill, green sunfish, and "bass." In this investigation no species of Gyrodactylid has been found to occur on either of the crappies and also on another member of the family *Centrarchidae*. Figure group 1.

Cleidodiscus longus sp. nov.

Host.—White Crappie *(Pomoxis annularis)*, Lake Decatur, Decatur, Ill.

Moderately small parasites devoid of body scales and internal spicules. Length about 0.626 mm. (0.492-0.713 mm.), width at level of cephalic lobes about 0.087 mm. (0.066-0.107 mm.), greatest body width about 0.106 mm. (0.098-0.123 mm.), width of peduncle at junction with haptor about 0.064 mm. (0.038-0.086 mm.). Haptor distinct, hexagonal in shape and broader than long, width about 0.110 mm. (0.076-0.123 mm.), length about 0.100 mm. (0.057-0.114 mm.). The two bars are non-articulate with each other. Anterior eye spots almost invariably farther apart than members of the posterior pair. Anchors similar in shape, bases bifurcate, superficial roots longer than deep roots. Anchor shafts dilated distally exhibiting a cavity within and meeting the anchor points to form a distinct internal angle. Bases of ventral anchors noticeably wider than bases of dorsal anchors. Ventral anchors longer than dorsal anchors. Length of ventral anchors about 0.043 mm. (0.038-0.051 mm.), width about 0.028 mm. (0.019-0.032 mm.), length of dorsal anchors about 0.037 mm. (0.031-0.046 mm.), width about 0.017 mm. (0.013-0.023 mm.). Each of the fourteen hooks is differentiated into base, shaft, sickle-shaped termination and opposable piece. The arrangement of the hooks is characteristic of forms in this genus whose bars are non-articulate with each other. Bases of hooks ovate, bases of number five shorter than the shafts. Bases of the remaining pairs of hooks elongate-ovate and about the same length as their respective shafts. Hooks of pairs numbers one and five are shorter than the remaining pairs of hooks. Gonads situated in the first portion of the posterior hody half. Testis elongate in shape and located posterior to the ovary. No apparent dilatation of the vas deferens to form a seminal vesicle. Two prostates present, the larger is elongate-sacculate and contains a finely granular colorless fluid, the smaller is sacculate and contains a coarsely granular yellowish fluid. Copulatory complex well developed and situated in a slender vestibule. Cirrus a long chitinous whip-like tube attenuated distally to a fine thread. Accessory piece consists of a chitinous structure with a deep groove which serves as a guide for the cirrus. The base of the accessory piece is articulated to that of the cirrus. Ovary ovate in shape, from one to two times as large as the testis and situated anterior to it. Vagina present on the left body margin about midway the length, vaginal canal a long chitinous tube emptying mesially into the seminal receptacle. Uterine pore located to the right of the copulatory complex base on the ventral body surface. Excretory and digestive systems as described for the group.

This species occurs in mixed infestations with *Cleidodiscus vancleavei* n. sp., *Cleidodiscus capax* n. sp. and *Cleidodiscus uniformis* n. sp. It has been taken only from the white crappie. *Cleidodiscus uniformis* n. sp. possesses a copu-

latory complex similar to but shorter than that of *Cleidodiscus longus* n. sp. The vaginae of the two species are almost identical. The chief difference is the dissimilarity between the anchors and bars of each. The bases of the two pairs of anchors of *C. longus* are different in size and the anchor shafts are greatly dilated to form an internal angle at their junction with the points, whereas the bases of the two pairs of anchors of *C. uniformis* are almost identical in width, without marked dilatation of the shafts and are regularly recurved with no internal formation of an angle. The bars of *Cleidodiscus longus* are distinctive in themselves. Figure group 11.

Cleidodiscus uniformis sp. nov.

Host: White Crappie *(Pomoxis annularis)*, Lake Decatur, Decatur, Ill.

Relatively small parasites with body scales and internal spicules. wanting. Length about 0.583 mm. (0.398-0.738 mm.), width at level of cephalic lobes about 0.080 mm. (0.065-0.114 mm.), greatest body width about 0.097 mm. (0.075-0.147 mm.), width of peduncle at junction with haptor about 0.062 mm. (0.034-0.092 mm.). Haptor distinct, hexagonal in shape and broader than long, width about 0.107 mm. (0.076-0.127 mm.), length about 0.093 mm. (0.062-0.114 mm.). Spatial relationships between individual members of the pairs of eye spots variable. Anchors similar in shape, bases bifurcate, superficial roots longer than deep roots. Anchor shafts hollow, without marked dilatation and regularly recurved without formation of an angle at the junction with the points. Lengths and widths of the anchors approximately equal. Length of ventral anchors about 0.032 mm. (0.026-0.034 mm.), width about 0.017 mm. (0.013-0.019 mm.), length of dorsal anchors about 0.032 mm. (0.026-0.036 mm.), width about 0.016 mm. (0.013-0.018.). Each of the fourteen hooks is differentiated into base, shaft, sickle-shaped termination and opposable piece. The arrangement of the hooks is common to members of the genus whose bars are not articulated with each other. Bases ovate to elongate-ovate. Length of hooks numbers one and five conspicuously shorter than the rest of the pairs of hooks. Gonads situated in the first portion of the posterior body half. Testis ovate, slightly smaller than the ovary and situated dorso-posterior to the ovary. No evident dilatation of the vas deferens to form a seminal vesicle. Two prostates present, larger member irregularly sacculate and filled with a finely granular, colorless fluid, smaller member elongate and containing a coarsely granular yellowish fluid. Copulatory complex well developed and located in a slender vestibule. Cirrus a long chitinous whip-like tube attenuated distally to a fine thread. Accessory piece consists of a chitinous structure with a deep groove which serves as a guide for the cirrus. The base of the accessory piece is articulated to the base of the cirrus. Ovary ovate in shape, and slightly larger than the testis. Vagina present on the left body margin near the mid-length of the body, vaginal canal a long chitinous tube terminating at the seminal receptacle. Uterine pore situated to the right of the copulatory complex on the ventral body surface. Excretory and digestive systems common to the group.

This form occurs in mixed infestations with *C. vancleavei* n. sp., *C. capax*

n. sp., and *C. longus* n. sp. It has been recovered only from the white crappie. The vagina of this species is almost identical with that of *C. longus*. The copulatory complex is similar to but shorter than that of *C. longus*. Whereas the shafts of *C. longus* are markedly dilated to form an internal angle at the junction with the points, the converse exists in the anchors of *C. uniformis*. The ventral anchor bases of *C. longus* are much wider than the dorsal bases but in *C. uniformis* they are approximately equal. In addition to the above information, the bars of the two species in question are markedly different and no forms with intergrading bars have been observed. See Figure group 3.

Cleidodiscus vancleavei sp. nov.

Host.—White Crappie *(Pomoxis annularis)*, Lake Decatur, Decatur, Ill.

Relatively small parasite with body scales and internal spicules wanting. Length about 0.563 mm. (0.399-0.681 mm.), width at level of cephalic lobes about 0.068 mm. (0.042- 0.089 mm.), greatest body width about 0.070 mm. (0.057-0.089 mm.), width of peduncle at junction with haptor about 0.047 mm. (0.036-0.067 mm.). Haptor distinct, hexagonal in shape and broader than long, width about 0.104 mm. (0.089-0.124 mm.), length about 0.086 mm. (0.074-0.105 mm.). The two bars are non-articulate with each other. Anterior eye spots almost invariably farther apart than members of the posterior pair. Anchors similar in shape, bases slightly bifurcate, superficial roots longer than deep roots. Anchor shafts solid and make junction with the points to form an internal angle. Ventral anchors slightly longer than dorsal anchors. Bases of the two pairs of anchors not noticeably different in width. Length of ventral anchors about 0.039 mm. (0.033-0.044 mm.), width about 0.019 mm. (0.013-0.023 mm.), length of dorsal anchors about 0.036 mm. (0.029-0.042 mm.), width about 0.017 mm. (0.015-0.019 mm). Each of the fourteen hooks is differentiated into base, shaft, sickle-shaped termination and opposable piece. The arrangement of the hooks is characteristic of forms in this genus whose bars are non-articulate with each other. Bases of hooks of pair number five ovate and shorter than the shaft, bases of remaining hooks elongate. Bases of pair number one about the same length as the shaft. Bases of remaining hooks are longer than their respective shafts. Hooks of pair number five noticeably shorter than the rest of the hooks. Gonads located in the first portion of the posterior body half. Testis relatively small and situated posterior to the ovary. Vas deferens expands near the cirrus base to form a tubular seminal vesicle. Two prostates present, one containing a finely granular colorless fluid and the other filled with a coarsely granular faintly yellowish fluid. Copulatory complex well developed and situated in a small vestibule. Cirrus a short chitinous tube, base relatively large with shaft tapered to a point. Accessory piece a chitinous structure partially enclosing the base of the cirrus and making one complete circle around the short cirrus shaft. Accessory piece base is articulated to the base of the cirrus. Ovary ovate and much larger than the testis and with spatial relationships as given above. Vagina present on the left body margin about half way its length, vaginal canal short, emptying mesially into a transparent seminal receptacle.

Uterine pore located on the ventral body surface just anterior to the base of the copulatory complex. Excretory and digestive systems as given for the group.

This parasite occurs in mixed infestations with *C. longus* n. sp., *C. capax* n. sp., and *C. uniformis* n. sp. on the gills of the white crappie. While the general morphology of this species is similar to that of the rest of the members of the genus with the bars non-articulate, the characteristic copulatory complex together with the presence of a relatively large spine projecting from the posterior border of each bar distinguishes it immediately from all related forms. See Figure group 10.

Cleidodiscus articularis sp. nov.

Host.—Long-eared Sunfish *(Xenotis megalotis)*, Embarrass River, Urbana, Ill.

Relatively small gill parasites with surface scales and internal spicules wanting. Length about 0.470 mm. (0.360-0.615 mm.), width at level of cephalic lobes about 0.062 mm. (0.049-0.082 mm.), greatest body width about 0.068 mm. (0.049-0.079 mm.), width of peduncle at junction with haptor about 0.041 mm. (0.028-0.067 mm.). Haptor distinct, disc-like and broader than long, width about 0.072 mm. (0.061-0.086 mm.), length about 0.055 mm. (0.047-0.057 mm.). Anchors similar in size and shape, bases non-bifurcate, deep roots vestigial. Distance between anterior eye spots usually greater than distance between members of the posterior pair. Anchor shafts solid and regularly recurved without formation of an internal angle at the junction with the hollow points. Length of anterior anchors about 0.033 mm. (0.032-0.038 mm.), width about 0.010 mm. (0.009-0.013 mm.), length of posterior anchors about 0.032 mm. (0.028-0.038 mm.), width about 0.010 mm. (0.008-0.011 mm.). Each of the fourteen hooks is differentiated into base, shaft, sickle-shaped termination and opposable piece. The arrangements of the hooks is characteristic of forms in the genus whose bars are articulated with each other. Bases of all hooks sub-spherical in shape and much shorter than the shafts. Hooks of pair number one slightly shorter than the rest of the hooks. Gonads situated in the second body half. Testis ovate, about the same size as the ovary and located dorso-posteriorly to it. Vas deferens slightly dilated to form a tubular seminal vesicle near the cirrus base. Two prostates present, smaller member somewhat bulbular in shape and containing a finely granular colorless fluid, larger member bulbular in shape and filled with a coarsely granular yellowish fluid. Copulatory complex well developed and situated in a vestibule. Cirrus a chitinous tube with a large base, doubly recurved and ending in a forked termination. Accessory piece a chitinous structure of an aviform nature with its base articulated with the base of the cirrus. Ovary sub-spherical in shape, about the same size as the testis and located antero-ventrally to it. Vagina present on the left body margin near the mid-length, vaginal canal a short chitinous tube emptying into the small seminal receptacle. Uterine pore situated ventrally and to the right of the

copulatory complex. Excretory and digestive systems as described for the group.

This species occurs in mixed infestations with *Onchocleidus distinctus* n. sp., *Cleidodiscus bedardi* n. sp., *Onchocleidus acuminatus* n. sp. and an undescribed species of *Cleidodiscus*. *Cleidodiscus oculatus* Mueller, 1934, structurally stands closer to this species than does any other member of the genus. Both forms have the bars modified to articulate with each other. The arrangement of the hooks is unique in that numbers six and seven are not located on the dorsal surface of the haptor but on the ventro-posterior surface. *C. articularis* is readily distinguishable from *C. oculatus* by the presence of the doubly recurved cirrus and an aviform accessory piece. The former species has been taken only from the gills of the long-eared sunfish whereas the latter form is common only to the pumpkinseed sunfish *(Eupomotis gibbosus)* See Figure group 9.

Cleidodiscus bedardi sp. nov.

Host.—Long-eared Sunfish *(Xenotis megalotis)*, Embarrass River, Urbana, Ill.

Relatively small parasites devoid of internal spicules and surface scales. Length about 0.412 mm. (0.285-0.495 mm.), width at level of cephalic lobes about 0.056 mm. (0.047-0.067 mm.), greatest body width about 0.080 mm. (0.057-0.103 mm.), width of peduncle at junction with haptor about 0.057 mm. (0.038-0.065 mm.). Haptor distinct, sub-discoidal in shape and broader than long, width about 0.087 mm. (0.059-0.100 mm.), length about 0.059 mm (0.051-0.067 mm.). The two bars are non-articulate with each other. Distance between members of the anterior pair of eye spots usually greater than the distance between the posterior members. Anchors similar in shape, bases bifurcate, superficial roots longer than deep roots. Anchor shafts solid, making junctions with the points with only a suggestion of an internal angle. Ventral anchors slightly longer than dorsal anchors. Ventral bases not conspicuously wider than dorsal bases. Length of ventral anchors about 0.027 mm. (0.023-0.034 mm.), width about 0.012 mm. (0.009-0.015 mm.), dorsal anchor length about 0.024 mm. (0.021-0.032 mm.), width about 0.011 mm. (0.009-0.015 mm.). Each of the fourteen hooks is differentiated into a base, shaft, sickle-shaped termination and opposable piece. The arrangement of the hooks is characteristic of forms in this genus whose bars are non-articulate with each other. Bases of all hooks ovate and about the same length as the shafts, base of number five shortest of all. Ventral bar variable, often bent posteriorly in the middle and always much larger than the dorsal bar. Dorsal bar often variable in shape. All hooks approximately the same length. Gonads located in the first portion of the second body half. Testis ovate, situated dorsoposteriorly to the ovary. A fusiform seminal vesicle is formed just posterior to the cirrus base by a dilatation of the vas deferens. Only one prostate has been observed; it is sacculate and contains a coarsely granular yellowish fluid. Copulatory complex well developed and situated in a relatively large vestibule. Cirrus a curved chitinous tube tapered distally to a fine point. Accessory

piece a solid chitinous rod with a chelate termination. The accessory piece is articulated to the base of the cirrus. Ovary sub-spherical in shape, situated antero-ventrally to the testis and about twice its size. Vagina present on the left body margin near the mid-length, vaginal canal short, emptying into a small seminal receptacle lying nearly parallel with the body wall. A pseudo-vagina is present immediately anterior to the vagina. Uterine pore located on the ventral body surface at the right of the copulatory complex. Excretory and digestive systems common to the group.

This species occurs in mixed infestations with *C. articularis* n. sp., *Onchocleidus distinctus* n. sp., *Onchocleidus acuminatus* n. sp. and an undescribed species of *Cleidodiscus*. It has been taken only from the long-eared sunfish from the Embarrass River south of Urbana, Illinois. It is immediately recognizable by the striking difference in the sizes of the dorsal and ventral bars, the ventral being much larger; the presence of a pseudo-vagina; and the chelate accessory piece. The anchors are relatively small with deeply bifurcate bases. The above structural details are radically different from those of any other described species of the genus *Cleidodiscus*. See Figure group 12.

Genus **ONCHOCLEIDUS** Mueller, 1936, emend. Mizelle, 1936.

Diagnosis.—*Tetraonchinae* with the intestine bifurcate but confluent posteriorly. Median sagittal plane passing through testis and ovary. Vagina not always present but when so it lies on the right body margin near the mid-length. Copulatory complex weakly developed, cirrus a slender chitinous tube, at times with a spiral fin or cirral thread around the shaft, at times corkscrew-like in nature. Accessory piece may be wanting but when present its base is never articulated with the base of the cirrus. Haptor generally distinct and well set off from the body, hexagonal or pentagonal in shape. The two bars present are never articulated with each other. Two pairs of eyes present, anterior pair always smaller. Fourteen hooks present, each of which may be solid and differentiated into a base, shaft, sickle-shaped termination and opposable piece, or each of them may exist in the nature of a solid or hollow cylindrical body with a sickle-shaped termination and opposable piece distally. A pair of hooks is almost invariably present between the ventral anchors in the region of the shafts and points. Vitellaria well developed as two lateral bands composed of individual follicles. Present on the gills of fresh-water fishes. Type species, *O. ferox* (Mueller, 1934.).

Onchocleidus principalis sp. nov.

Host.—Kentucky Bass *(Micropterus pseudaplites)*, Salt Fork of the Big Vermilion River, Homer, Ill.

Relatively small parasites devoid of body scales and internal spicules. Length about 0.467 mm. (0.369-0.631 mm.), width at level of cephalic lobes about 0.079 mm. (0.066-0.108 mm.), greatest body width about 0.096 mm. (0.070-0.127 mm.), width of peduncle at junction with haptor about 0.057 mm. (0.028-0.070 mm.). Haptor distinct, hexagonal or pentagonal in shape and broader than long, width about 0.098 mm. (0.078-0.125 mm.), length

about 0.066 mm. (0.051-0.082 mm.). The two bars are not articulated with each other. Anterior eye spots generally closer together than members of the posterior pair. Anchors similar in shape, bases slightly bifurcate, superficial roots, longer than deep roots. Anchor shafts solid and regularly recurved without significant formation of an angle at the junction with the points. Ventral anchors slightly longer than dorsal anchors. Bases of ventral anchors not conspicuously wider than bases of dorsal anchors. Length of ventral anchors about 0.033 mm. (0.028-0.038 mm.), width about 0.18 mm. (0.015-0.021 mm.), length of dorsal anchors about 0.031 mm. (0.027-0.034 mm.), width about 0.015 mm. (0.013-0.017 mm.). Each of the fourteen hooks present is differentiated into a base, shaft, sickle-shaped termination and opposable piece. Bases elongate, bases of pair number one about the same length as their shafts, bases of pair number five shorter than their shafts, base of remaining pairs, longer than their respective shafts. Hook pairs numbers one and five slightly shorter than members of the remaining pairs. Gonads situated in the posterior body half. Testis located dorsal to ovary. Vas deferens dilates to form a conspicuous fusiform seminal receptacle just posterior to the cirrus base. Two prostates present, larger member elongate and contains a finely granular, colorless fluid, smaller member bulbular in shape and filled with a coarsely granular, yellowish fluid. Copulatory complex weakly developed and situated in a relatively small vestibule. Cirrus a chitinous corkscrew-like tube. Accessory piece consists of a solid chitinous piece with a key-hole effect at the distal end through which the cirrus passes. The base is not articulated with the cirrus base. Ovary ovate in shape and about twice the size of the testis. Vagina present on the right body margin about midway the body length, vaginal canal a long chitinous tube emptying distally into the seminal receptacle. Uterine pore situated to the right of the copulatory complex. Excretory system common to the group but with an additional pair of lateral ducts passing toward the lateral body regions at the level of the seminal receptacle. Openings for these canals have not been located. Digestive system common to the group.

This parasite has been recovered only from the Kentucky bass *(Micropterus pseudaplites)*. It is the first and only parasite in this work to be taken from the gills of this host. This form is singular in that it is the only member of the genus *Onchocleidus* Mueller, 1936, that has each of the fourteen hooks differentiated into base shaft, sickle-shaped termination and opposable piece. While this character is common to the genus *Cleidodiscus* Mueller, 1934, the possession of other characters as vagina on the right, cirrus corkscrew-like and without articulation of the accessory piece to its base, definitely places it in the genus *Onchocleidus*. The bars, anchors, vaginal tube and hooks are distinctive. See Figure group 2.

Onchocleidus interruptus sp. nov.

Host.—Yellow Bass *(Morone interrupta)*, Lake Decatur, Decatur, Ill.; Lake Senachwine, Henry, Ill.

Relatively small parasites devoid of surface scales and internal spicules. Length about 0.407 mm. (0.285-0.508 mm.), width at level of the cephalic

lobes about 0.073 mm. (0.067-0.080 mm.), greatest body width about 0.085 mm. (0.066-0.104 mm.), width of peduncle at junction with haptor about 0.057 mm. (0.046-0.070 mm.). Haptor distinct, hexagonal or pentagonal in shape and broader than long, width about 0.097 mm. (0.086-0.133 mm.), length about 0.078 mm. (0.066-0.095 mm.). The two bars are non-articulate with each other. Spatial relationships between eye spots of each individual pair variable. Anchors similar in shape, bases bifurcate, superficial roots longer than deep roots. Anchor shafts solid, making junction with the points to form an internal angle at this locus. Bases of ventral anchors noticeably wider than bases of dorsal anchors, ventral anchor length greater than dorsal anchor length. Length of ventral anchors about 0.045 mm. (0.040-0.052 mm.), width about 0.024 mm. (0.019-0.032 mm.), length of dorsal anchors about 0.040 mm. (0.036-0.050 mm.), width about 0.014 mm. (0.013-0.021 mm.). The hooks are not differentiated into bases and shafts but consist of solid, elongate, cylindrical structures each with a sickle-shaped termination and opposable piece distally. The arrangement of the hooks is characteristic of the genus. Members of hook pair number one conspicuously larger and number five conspicuously smaller than members of the remaining pairs. Testis ovate, from four to six times as large as the ovary and situated posterior to it. Vas deferens dilated immediately posterior to the cirrus base to form an infundibuliform seminal receptacle. Two prostates present, the larger a sacculate structure containing a finely granular, colorless fluid and superimposed on a smaller botuliform structure containing a coarsely granular yellowish fluid. Copulatory complex weakly developed and located in a relatively small vestibule. Cirrus a straight chitinous tube slightly attenuated distally, expanding terminally, and with a cirral thread wound around the shaft. Accessory piece solid, with a key-hole effect terminally through which one of the loops of the cirral thread passes. The uterine pore is situated ventrally near the copulatory complex. Excretory and digestive systems common to the group. Vagina and seminal receptacle apparently wanting.

This parasite has been collected only from the yellow bass *(Morone interrupta)* and is the only monogenetic form in this work to be recovered from the gills of this host. It is easily recognizable by the massive testis and characteristic bars and anchors. Members of the ventral pair of anchors have the shafts noticeably bent in the direction of the points. The copulatory complex is similar to that *Onchocleidus distinctus* n. sp. Presumably this parasite possesses a marked degree of specificity for the yellow bas. See Figure group 4.

Onchocleidus mucronatus sp. nov.

Host.—Bluegill, *(Helioperca incisor)*, Orange-spotted Sunfish *(Allotis humilis)*, Pumkinseed Sunfish *(Eupomotis gibbosus)*, Hybrid between the Orange-spotted and Pumpkinseed, and Hybrid between the Bluegill and the Pumpkinseed Sunfishes, Lake Senachwine, Henry Ill.
Bluegill Sunfish, Lake Decatur, Decatur, Ill.
Orange-spotted Sunfish, Salt Fork of the Big Vermilion River, Homer, Ill.
Bluegill Sunfish, State Natural History Survey Pond, Urbana, Ill.

Relatively small parasites devoid of surface scales and internal spicules. Length about 0.503 mm. (0.426-0.820 mm.), width at level of cephalic lobes 0.051 mm. (0.041-0.098 mm.), greatest body width about 0.065 mm. (0.051-0.131 mm.), width of peduncle at junction with haptor about 0.042 mm. (0.019-0.075 mm.). Haptor distinct, hexagonal or pentagonal in shape and broader than long, width about 0.101 mm. (0.070-0.148 mm.), length about 0.098 mm. (0.075-0.139 mm.). The two bars are not articulated with each other. Anterior eye-spots usually farther apart than members of the posterior pair. Anchors similar in size and shape, bases bifurcate, superficial roots longer than deep roots. Anchor shafts solid, making junction with the points to form a distinct internal angle. Length of ventral anchors about 0.057 mm. (0.051-0.067 mm.), width about 0.014 mm.)0.009-0.019 mm.), length of dorsal anchors about 0.057 mm. (0.051-0.074 mm.), width about 0.012 mm. (0.009-0.019 mm.). Each of the hooks except number five consists of a straight chitinous structure attenuated distally to end in a sickle-shaped termination and opposable piece. Hook number five possesses a base, shaft, sickle-shaped termination and opposable piece. The arrangement of the hooks is characteristic of the genus. Hooks numbers one and seven with an apparent cavity within, hook number two only slightly so. Hooks of pair number one noticeably longer, and number five conspicuously shorter than members of the other hook pairs. Gonads situated in the posterior half of the body. Testis almost spherical in shape and located posterior to the ovary. Vas deferens dilated slightly to form a long tube-like seminal vesicle near the cirrus base. Two prostrates present, larger member banana-shaped, containing a finely granular colorless fluid, smaller member sacculate and filled with a coarsely granular yellowish fluid. Copulatory complex weakly developed and situated in an elongate vestibule. Cirrus a chitinous tube tapered to a point and with a cirral thread around the shaft. Accessory piece a solid chitinous structure with a key-hole effect terminally through which the cirrus projects. The bases of the cirrus and accessory piece are non-articulate with each other. Ovary sub-spherical in shape, about one-third to one-half the size of the testis and situated anterior to it. Vagina on the right body margin near its mid-length, vaginal canal a short zigzag chitinous tube emptying into a small bag-like seminal receptacle. Uterine pore situated on the ventral body surface near the copulatory complex. Excretory and digestive systems as described for the group.

The species occurs in mixed infestations with *C. incisor* n. sp., *Onchocleidus dispar* Mueller, 1936, *Onchocleidus* acer Mueller, 1936, and an undescribed member of Cleidodiscus. Superficially the copulatory complex is similar to that of *O. dispar*. *Onchocleidus mucronatus* n. sp. possesses anchors that are approximately the same size whereas the two pairs of anchors of *O. dispar* greatly differ in size relationships with each other. *O. mucronatus* is the only described member of the genus *Onchocleidus* Mueller, 1936, with spines projecting from the posterior margins of the two bars. These spines are best seen in side view of the specimens. Representatives of this species from Lake Senachwine are nearly twice the size of those taken from Lake Decatur fishes. See Figure group 8.

Onchocleidus acuminatus sp. nov.

Host.—Long-eared Sunfish *(Xenotis megalotis),* Embarrass River, Urbana, Ill.

Relatively small parasites without surface scales or internal spicules. Length about 0.495 mm. (0.338-0.640 mm.), width at level of cephalic lobes about 0.066 mm. (0.052-0.095 mm.), greatest body width about 0.093 mm. (0.066-0.118 mm.), width of peduncle at junction with haptor about 0.053 mm. (0.038-0.068 mm.). Haptor distinct, hexagonal or pentagonal in shape and only slightly broader than long, width about 0.078 mm. (0.064-0.0104 mm.), length about 0.077 mm. (0.068-0.098 mm). The two bars are non-articulate with each other. Anterior eye spots almost invariably farther apart than members of the posterior pair. Anchors similar in size and shape, bases slightly bifurcate, superficial roots longer than deep roots. Anchor shafts solid, making junction with points to form an internal angle. Just proximally to the junction a spur-shaped structure arises from each shaft and projects above and parallel to the anchor point. Dorsal anchor slightly longer than ventral anchor, ventral base slightly wider than dorsal base. Length of ventral anchor about 0.047 mm. (0.040-0.051 mm.), width about 0.014 mm. (0.011-0.017 mm.), length of dorsal anchor about 0.048 mm. (0.040-0.053 mm.), width about 0.013 mm. (0.010-0.017 mm.). Each hook solid, and cylindrical in nature with a sickle-shaped termination and opposable piece distally. Hooks of pairs numbers one, six and seven noticeably larger than the rest of the hooks. The arrangement of the hooks is characteristic of the genus. Gonads located in the posterior half of the body. Testis ovate in shape and lying posterior to the ovary. Vas deferens dilated near the cirrus base to form a spindle-shaped seminal vesicle. Two banana-shaped prostates present, about the same size, one containing a colorless hyaline fluid, the other filled with a granular yellowish fluid. Copulatory complex weakly developed and enclosed within a slender vestibule. Cirrus a corkscrew-like chitinous tube with a moderate sized base. Accessory piece a ploughshare-shaped structure lying along-side the cirrus proximally and with a ring distally through which the cirrus passes. The bases of the accessory piece and cirrus are non-articulate with each other. Ovary ovate in shape, about the same size as the testis and situated anterior to it. Vagina present on the right body margin near the mid-length; vaginal canal a relatively long winding tube often making one or two loops before emptying mesially into the seminal receptacle. The uterine pore is situated to the right of the copulatory complex on the ventral body surface. Excretory and digestive systems as described for the group.

This form occurs in mixed infestations with *C. bedardi* n. sp., *C. articularis* n. sp., *Onchocleidus distinctus* n. sp., and an undescribed species of *Cleidodiscus*. The cirrus of this form resembles that of *O. principalis* n. sp., but the anchors possess spur-shaped projections near the points like *Onchocleidus acer* Mueller, 1936. The host of *Onchocleidus acuminatus* is different from either of its relatives. *O. acer* has been taken only from the pumpkinseed sunfish; *O. principalis* has been recovered only from the Kentucky bass, while *O. acuminatus* is limited to the long-eared sunfish. The bars, anchors, vagina

and vaginal tube of this species are distinctive in themselves. See Figure group 5.

Onchocleidus distinctus sp. nov.

Host.—Long-eared Sunfish *(Xenotis megalotis),* Embarrass River, Urbana, Ill.

Relatively small parasites without surface scales or internal spicules. Length about 0.476 mm. (0.344-0.590.), width at level of cephalic lobes about 0.065 mm. (0.048-0.072 mm.), greatest body width about 0.070 mm. (0.050-0.095 mm.), width of peduncle at junction with haptor about 0.046 mm. (0.032-0.057 mm.). Haptor distinct, hexagonal or pentagonal in shape, and broader than long; width about 0.078 mm. (0.064-0.110 mm.), length about 0.070 mm. (0.057-0.086 mm.). The two bars are non-articulate with each other. Anterior eye spots almost invariably farther apart than members of the posterior pair. Anchors similar in shape, bases slightly bifurcate, superficial roots longer than deep roots, anchor shafts with a small cavity in the distal portion. The shafts make junction with the points to form an internal angle. Ventral anchor slightly longer than dorsal anchor, ventral base not noticeably wider than dorsal base; length of ventral anchors about 0.035 mm. (0.032-0.038 mm.), width about 0.016 mm. (0.013-0.019 mm.), length of dorsal anchors about 0.034 mm. (0.030-0.036 mm.), width about 0.013 mm. (0.011-0.015 mm.). Hooks cylindrical in shape with a sickle-shaped termination and opposable piece distally. Pairs numbers one, six and seven hollow; pair number one conspicuously larger and number five conspicuously smaller than the rest of the hooks. The arrangement of the hooks is characteristic of the genus. Gonads located in the posterior half of the body. Testis ovate in shape, smaller than the ovary and situated posterior to it. Vas deferens expands to produce a fusiform seminal vesicle near the cirrus base. Two tubular prostates present, with attenuated ends; smaller member about three-fourths as large as the larger member and filled with a finely granular colorless fluid; larger member containing a coarsely granular fluid. Copulatory complex weakly developed and located in a small vestibule. Cirrus a short chitinous tube attenuated distally, and with a fine cirral thread coiled about its outer surface. Accessory piece a chitinous sleeve complete anteriorly and enclosing the cirrus. The base of the accessory piece is not articulated to the cirrus base. Vagina present on the right side of the body near the termination of the first body half, vaginal canal a short chitinous tube emptying mesially into a small seminal receptacle. Uterine pore situated on the ventral body surface near the copulatory complex. Excretory and digestive systems as described for the group.

This parasite occurs in mixed infestations with *C. bedardi* n. sp., *C. articularis* n. sp., *O. acuminatus* n. sp., and an undescribed species of *Cleidodiscus*. It has been recovered only from the long-eared sunfish. The cirrus superficially resembles the cirrus of *Onchocleidus mimus* Mueller, 1936. The accessory piece is wanting in *O. mimus* but is present in *Onchocleidus distinctus* n. sp. The vaginal canal, bars, slightly dilated and hollow anchors are conspicuously different from any other described member of the genus. See Figure group 6.

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EXPLANATION OF FIGURES

All drawings were made with a camera lucida at the same magnification. Structures of each species are placed in one group.

cc.	copulatory complex	v.	vagina
c.	cirrus	vt.	vaginal tube or canal
ap.	accessory piece	sr.	seminal receptacle
da.	dorsal anchor	db.	dorsal bar
va.	ventral anchor	vb.	ventral bar
aa.	anterior anchor	ab.	anterior bar
pa.	posterior anchor	pb.	posterior bar

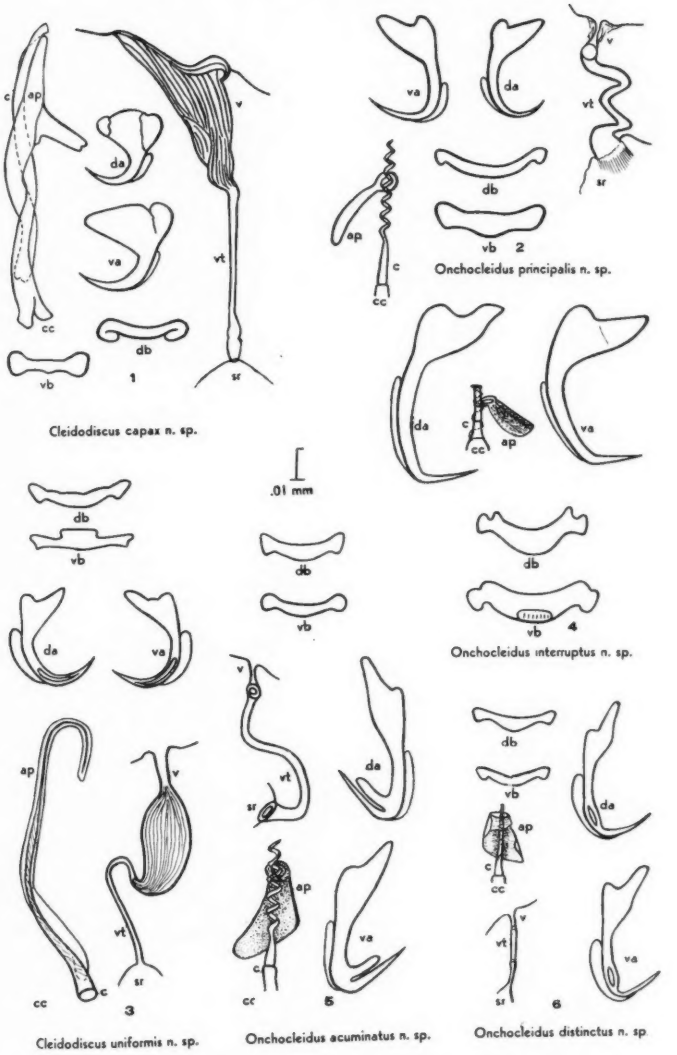

Figure groups: 1. *Cleidodiscus capax* n. sp.—2. *Onchocleidus principalis* n. sp.—3. *Cleidodiscus uniformis* n. sp.—4. *Onchocleidus interruptus* n. sp.—5. *Onchocleidus acuminatus* n. sp.—6. *Onchocleidus distinctus* n. sp.

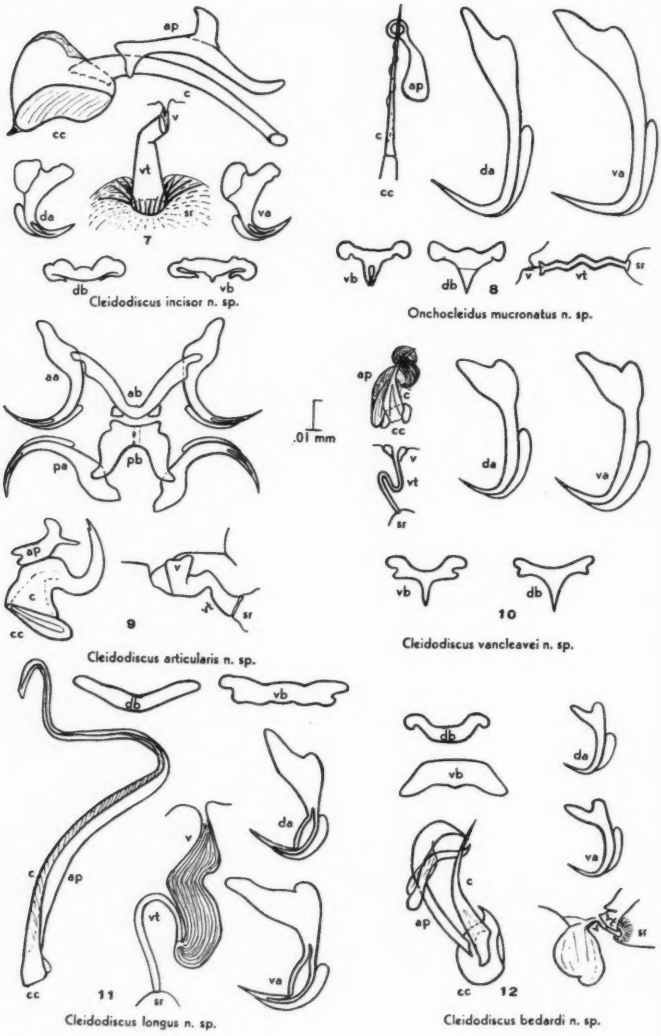

Figure groups: 7. *Cleidodiscus incisor* n. sp.—8. *Onchocleidus mucronatus* n. sp.—9. *Cleidodiscus articularis* n. sp.—10. *Cleidodiscus vancleavei* n. sp.—11. *Cleidodiscus longus* n. sp.—12. *Cleidodiscus bedardi* n. sp.

Notes on Some Parasitic Copepods and a Mite, Chiefly from Florida Fresh Water Fishes

Justus F. Mueller

During the summer of 1935 a number of different parasitic copepods were collected from fresh water fishes in Florida. A study of these forms indicates that they all belong to species previously described, although differing in certain characters from their published descriptions. These variations are discussed in this paper. The present author, in a recent paper, described as new three species of Ergasilidae from fishes of Oneida Lake, N. Y. These forms differed from any of Wilson's species in certain characters which at the time were regarded as of specific value. It has now been determined, as a result of comparison with the Florida material, that the original descriptions of these species cannot be held to apply too literally, and that a single species is subject to variations in different localities. Therefore, in this paper, the author's new species are reduced to synonymy, for reasons set forth in detail below. A species described as new by Bere, 1931, has also been declared a synonym for the same reason. In addition to the Copepoda collected, a species of water mite was taken from the gills of the bowfin, in Florida, on which it appears to have been a true parasite. This is evidently the first record of a mite parasitic upon the gills of a freshwater fish.

Argulus flavescens Wilson, 1916

Figs. 20-28

Host: *Aplites salmoides*, in Myakka River, near Sarasota; and *Amia calva*, in canals of Lake Okeechobee, near Clewiston, Florida. In gill chambers and mouth.

These arguli were abundant in the mouth of the large mouth bass. It seems likely that this is their normal host and habitat. Fifteen were taken from a single bass. Three were also taken from an Amia. Wilson secured only three female specimens, two from Amia, and one from the mud cat, Leptops. He remarks: "It seems probable that the mud cat is the real host of this species, and that the two specimens on the outside of the dogfish were only seeking temporary lodgement." It appears more probable to the author that the large mouth bass is the real host, and that the species may have been frequently overlooked on this fish because of its location in the mouth. It was found under and on the tongue, and on the sides of the mouth as far back as the region of the gill arches.

My specimens conform in general to Wilson's description, but are some-

what smaller—with a total length of 5 mm. as compared to 6 mm. given by Wilson. It seems probable that my specimens are younger, since the lateral branches of the stomach are not as developed as Wilson indicates in his figure. The color and pigmentation of the female is quite similar to Wilson's description; however, his drawings are somewhat limited, and for that reason the species is figured again here, Plate 3. The spinose raised area on the second joint of the maxillipeds is limited to the distal half of the joint, and is only half as large as figured by Wilson. The membranous edge of the sucking discs is supported by a series of jointed ribs, as figured by Wilson, but the interstices bear small raised areas or bosses, not shown by him.

The general form of the male, which Wilson did not observe, is similar to that of the female, but the abdomen is longer in proportion and the dorsal median eye is larger. The most conspicuous difference, however, appears in the pigmentation. The chromatophores are much lighter over the carapace and free thoracic segments. Large chromatophores occur in the abdomen only, over the seminal vesicles, but these are not so dense as those of the female, and are of a light brown color. Wilson states that the pigment of the female is jet black, but in my female specimens it is rather a dark brown. The respiratory areas are slightly different from Wilson's figure in that the larger area has an expanded posterior end, not shown by him (Fig. 27).

The differences noted cannot be considered to be of specific value. They are more plausibly interpreted as due to local variation, and possibly to some degree as the result of errors of observation.

The present record extends the range of the species to Florida.

Ergasilus centrarchidarum Wright, 1882

Host: *Aplites salmoides*.
Locality: Clewiston, Florida.

My specimens agree in general with Wilson's description (1911). The species is readily recognized by its small size, characteristic form, rather plump egg strings, and by having all rami of the swimming legs three-jointed. Wilson states: "Body of a clear cartilage color, translucent in young females, but becoming dense and opaque in adults." He does not mention the presence of pigment. My specimens have scattered patches of light blue pigment on the ventral surface, and the eye is an intense pure blue.

Ergasilus elegans Wilson, 1916
Figs. 11-19

Hosts: species of Ameiurus and Ictalurus, on gill filaments.
Locality: Peace River, near Fort Ogden; canals of Lake Okeechobee, near Clewiston; and Myakka River, near Sarasota, all in Florida.

This species was very abundant on its hosts. My material agrees with Wilson's description in the general characters, but differs in certain points. The egg strings as figured by Wilson are only half as long as the body an-

terior to their point of origin, but in my material they are longer than the entire body anterior to that point. The species is peculiar in having the endopod of the first swimming legs and the exopod of the fourth two jointed. My specimens differ from Wilson's description in the arrangement of the spines and setae on the swimming legs as follows: For the first exopod Wilson gives I-0, 0-I, II-5. In my specimens this is I-0, 0-1, III-4. For the first endopod Wilson gives 0-I, II-5. In mine this is 0-1, II-4. The third exopod is given by Wilson as I-0, 0-1, I-5. In my material it is I-0, 0-1, I-6. The fourth exopod is given by Wilson as I-0, I-5. In my form it is 0-0, I-5. I fail to find in these specimens the patches of pale brick red noted by Wilson. The pigment consists only of patches of deep purplish blue arranged in two irregular lines along the ventral surface.

Ergasilus versicolor Wilson, 1911

Figs. 1-7

Synonym: *Ergasilus celestis* Mueller, 1936.
Hosts: *Ameiurus nebulosus*, on gills.
Locality: Myakka River, near Sarasota, Florida.

In this form, as in *caeruleus*, the exopod of only the fourth swimming leg is two jointed; all other rami of the swimming legs are three jointed. There are differences in my specimens from Wilson's description. Wilson has described the species as highly pigmented, with brilliant violet purple, rust brown, yellow, and black. This pigment is entirely lacking in my specimens, which are of a pale cartilage color. The arrangement of the spines and setae also differs somewhat.

In a recent paper the author described as new *Ergasilus celestis*, from Anguilla and Lota, in Oneida Lake. This species was distinguished from *versicolor* by differences similar to those noted in the Florida material. The Oneida Lake forms likewise had no pigment, and the arrangement of the spines and setae on the swimming legs was different from either Wilson's description or the Florida material.

In the light of comparative study of all of these forms, it is clear that they are a single variable species. Hence *E. celestis* is reduced to synonymy with *E. versicolor*.

For comparison, the arrangement of spines and setae in these three forms is tabulated here.

	E. versicolor Wilson	"*E. celestis*" Mueller	*E. versicolor* Florida
First exopod	I-0, 0-1, II-4	I-0, 0-1, II-5	I-0, 0-1, III-4
endopod	0-1, 0-2, I-3	0-1, 0-1, II-4	0-1, 0-1, III-4
Second exopod	I-0, 0-1, I-4	I-0, 0-1, 0-6	I-0, 0-1, I-5
endopod	0-1, 0-2, II-4	0-1, 0-2, I-4	0-1, 0-2, I-4
Third exopod	I-0, 0-1, I-5	I-0, 0-1, 0-6	I-0, 0-1, I-5
endopod	0-1, 0-2, I-4	0-1, 0-2, I-4	0-1, 0-2, I-4
Fourth exopod	0-0, I-5	0-0, 0-5	0-0, I-4
endopod	0-1, 0-2, I-3	0-1, 0-2, I-3	not observed.

The second antennae of the Florida specimens show a constant and characteristic difference from those of New York State specimens, or from Wilson's figures, in that the terminal claw is noticeably constricted just beyond the elbow, and this joint is longer than in specimens from the other two localities (compare Figs. 1 and 2). Wilson's specimens were from Indiana, Illinois, and Iowa.

Ergasilus caeruleus Wilson, 1911

Synonyms: *Ergasilus confusus* Bere, 1931; *E. skrjabini* Mueller, 1936.

The author found this species on *Lepibema chrysops, Stizostedion vitreum,* and *Percopsis omisco-maycus,* in Oneida Lake. Because of certain differences in the setae of the swimming legs it was regarded as a new species. After further study, and in the light of findings with regard to variation in the two species discussed above, it is clear that these differences are not of specific value, and hence *E. skrjabini* is reduced to synonymy. Bere, 1931, likewise described a form very similar to *E. caeruleus,* under the name *E. confusus.* This copepod occurred on the yellow perch, wall eyed pike, rock bass, small mouth bass, lake trout, cisco, and white fish, in several lakes in Wisconsin. It does not differ from *caeruleus* to any greater degree than *E. skrjabini.* Hence *E. confusus* is also declared a synonym of *E. caeruleus.* Like *E. versicolor, E. caeruleus* has only the exopod of the fourth swimming leg two jointed; all others are three jointed. This feature is exhibited by both Bere's form and my specimens from Oneida Lake and Florida. For comparison, the arrangement of spines and setae in these three forms is given here.

	E. caeruleus Wilson	*E. confusus* Bere	*E. skrjabini* Mueller
First exopod	I-0, 0-1, II-5	I-0, 0-1, III-4	I-0, 0-1, II-5
endopod	0-1, 0-1, 0-5	0-1, 1-1, II-4	0-1, 0-1, II-4
Second exopod	0-1, I-1, 0-5	0-0, 0-1, I-5	0-0, 0-1, 0-6
endopod	0-1, 0-2, 0-5	0-1, 0-2, I-4	0-1, 0-2, I-4
Third exopod	0-1, 0-1, 0-5	0-0, 0-1, 0-6	0-0, 0-1, 0-4
endopod	0-1, 0-2, 0-4	0-1, 0-2, 0-5	0-1, 0-2, I-4
Fourth exopod	I-1, 0-5	0-0, 0-5	0-0, 0-5
endopod	I-1, 0-2, 0-4	0-1, 0-2, 0-3	0-2, 0-2, I-3

Wilson states that the species is pigmented with patches of a deep purplish blue. Bere's form is described as pigmented with patches of blue. *E. skrjabini* also carries a blue pigment similarly arranged over the ventral surface. All three forms show peculiar notches on the claw of the second antennae, first figured by Wilson. The general proportions of the body and egg strings are similar, though not as figured by Wilson, and all three forms have the first joint of the second antennae greatly inflated. It is therefore regarded as conclusive that both *E. confusus* and *E. skrjabini* are synonyms of *E. caeruleus.*

The author has compared the following material: cotypes of *Ergasilus caeruleus* Wilson, U.S.N.M. No. 39554, and specimens of *E. confusus* Bere,

U.S.N.M. No. 63834, determined by Bere. The first joint of the second antennae is not as inflated in Wilson's material as in mine, but the general characters are sufficiently close to indicate that all three forms are the same species. As a peculiar variation, I have one collection of specimens, No. 756, from *A. salmoides*, Cleveland, N. Y., in which the claw of the second antenna is smooth along its inner edge, lacking the notches and bosses regularly found in other specimens.

Ergasilus megaceros Wilson, 1916

Synonym: *Ergasilus fragilis*, Mueller, 1936.

This species was first described by Wilson from the lamellar plates in the nasal fossae of a Fulton cat, *Ictalurus anguilla*. The author found a copepod upon the gills of *Leucosomus corporalis*, in Oneida Lake, which again was not recognized as Wilson's species because of differences in the setae of the swimming legs. These differences are given here. Only the first two pairs of legs were observed in my specimens.

	E. megaceros Wilson	*E. fragilis* Mueller
First exopod	I-0, I-1, I-6	I-0, 0-1, III-4
endopod	0-I, 0-1, 0-6	0-1, 0-1, II-4
Second exopod	I-0, I-1, I-5	I-0, 0-1, II-5
endopod	0-I, 0-2, I-4	0-1, 0-2, I-4

There are probably other differences in the third and fourth swimming legs, but these could not be favorably observed in my material. The species is characterized by having the endopods of the first and fourth swimming legs longer than the exopods. The first antennae are also unusually large. My specimens showed these characters. They also have patches of sky blue pigment on the ventral surface, as noted by Wilson, and an intensely blue eye.

As a result of this study it is clear that the spines and setae of an Ergasilid cannot be given too much weight as specific characters, since they vary in different regions in the same species. It is also clear that the color, distribution, and amount of pigment are not constant characters, since pigment may be entirely absent in certain localities in a species heavily pigmented in other places, as in the case of *E. versicolor*.

Parasitic Hydrachnoidea

At Clewiston, Florida, a number of mites were taken from the gills of an Amia caught in the ditches draining into Lake Okeechobee. About 25 were taken from a single fish. This mite is shown in figures 8-10. It is about 0.6 mm. in length, and appears to be the larva of one of the aquatic mites. This appears to be a unique occurrence, as mites are not known to be parasitic upon fishes. The second, third, and fourth legs are similar in structure (Fig. 9). The first legs have a different type of terminal claw (Fig. 10). The chelicers have their terminal joints armed with numerous setae, but appear to have no specilaized pincers or claws. These mites are being sent to Dr. H. E. Ewing of the U. S. National Museum for identification.

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Plate 1—*Ergasilus versicolor* and Mite

FIGURES

1. *E. versicolor*, from Florida, second antenna.
2. *E. versicolor*, from New York, second antenna.
3. Florida specimen, mouth parts. First maxillæ not shown.
4–7. First, second, third, and exopod of fourth swimming leg, Florida material.
8. Mite from gills of Amia.
9. Fourth leg of mite.
10. Tip of first leg.

Plate 2—*Ergasilus elegans*, from Florida

11. Female with egg sacs, from *Ameiurus nebulosus*.
12–13. First and second antennæ.
14. Mouth parts.
15–18. First, second, third, and fourth swimming legs.
19. Genital segment and abdomen.

Plate 3—*Argulus flavescens*, from Florida

20. Dorsal view of female from large mouth bass.
21. Dorsal view of male.
22. Antennæ, outline of eye indicated.
23–24. Posterior maxilliped of female.
25. Posterior leg of female, proximal joints.
26. Proximal joints of posterior leg of male.
27. Respiratory areas, female. Outline of stomach indicated by dotted line.

PLATE 1

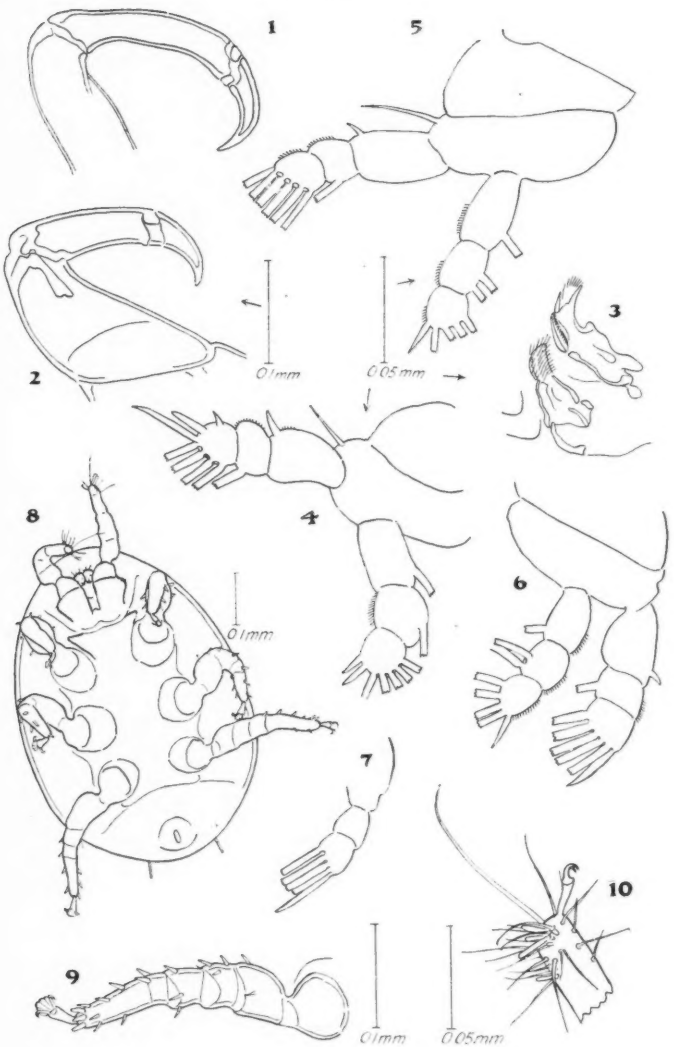


PLATE 2

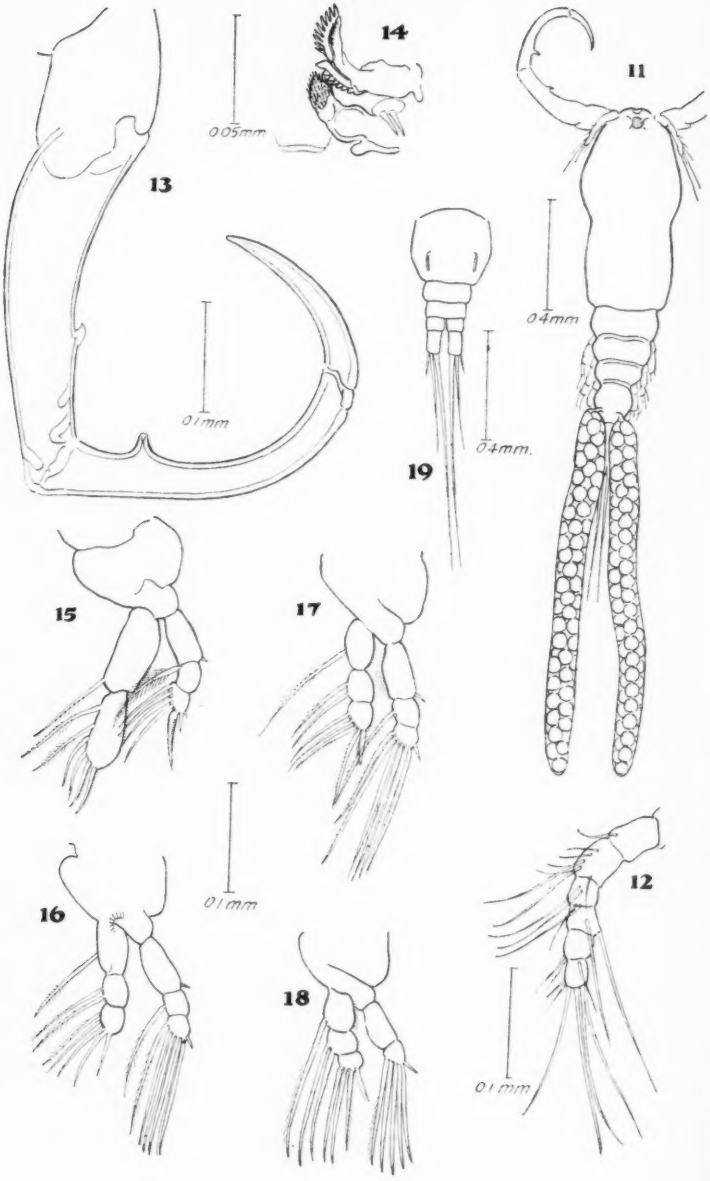
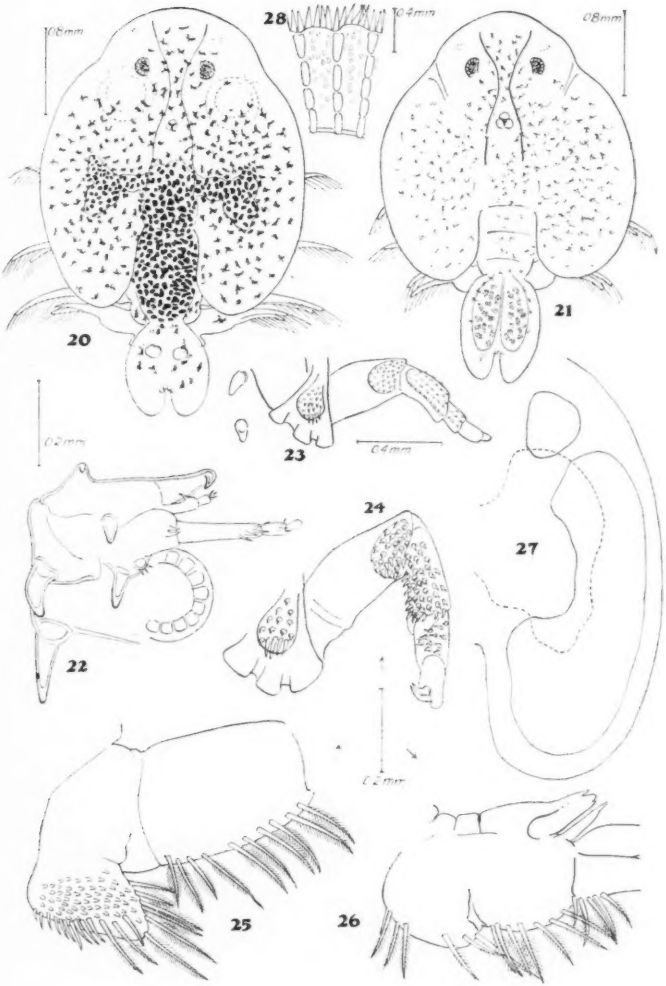


PLATE 3



The Life History of the Fan-tailed Darter

Catonotus flabellaris flabellaris (Rafinesque)*

Charles T. Lake

Introduction

The fan-tailed darter has been known to science since 1819, when it was described by Rafinesque from specimens secured in Kentucky, but little has been published concerning its development, life history or habits.

Forbes and Richardson (1920, p.314) mentioned briefly the food of this species and recorded four females about ready to spawn, taken in the latter part of May. Greeley (1926, p.64) recorded several specimens with eggs, taken in tributaries of the Genesee, and gave some information on nests, food and habitat. Adams and Hankinson (1928, p.465) summarized about all that had been learned about the species, and very little has been added since.

Jordan and Copeland (1896, p.20) termed this fish "The Darter of Darters. Hardiest, wiriest, wariest of them all, it is the one which is most expert in catching other creatures, and the one which most surely evades your clutch. It is a slim, narrow, black, pirate-rigged little fish, with a long pointed head, and a projecting, prow-like lower jaw." In western New York this small inhabitant of streams and lowland lakes is no doubt more abundant than any of its relatives. It usually prefers the swifter, stony stretches of the brooks and creeks, although occasionally ranging into the rivers and lakes. The abundance of the species and its ability to survive in breeding troughs and under laboratory conditions led to its selection for study.

Habitat Relationships

Field observations were concentrated in Black Creek, a tributary of the Genesee river in Monroe county, N. Y., particularly in that section of the stream near Buckbee's Corners, about twelve miles southwest of Rochester. In the riffles of this section of the stream the bottom, in general, is gravelly, with admixtures of rubble and sand. The stretches between riffles are mud-bottomed and weedy. Throughout the greater part of its length Black Creek is a slowly moving stream, but in the section selected for study a considerable current is evident in the riffles and for some distance above them. The breeding grounds discovered at this place extend for a distance of fifty yards above the riffles, with the water varying in depth from a few inches to two feet. A stick thrown into the current floated through a measured distance at the rate of one-half a foot per second or about one-third a mile per hour.

* A contribution from the Department of Zoology, University of Rochester.

While nests were found throughout this section, the greater number were concentrated in the comparatively narrow areas of bottom paralleling the shorelines about one-half the distance to the center of the stream. Nests in the section above the riffles out-numbered those in the riffles proper about three to one. This would indicate that within limits, depth of water and strength of current are factors in the selection of the nest site. No nests were found in the slack-water areas or in the roughest water of the riffles. Moreover, the fan-tailed darter shows a decided preference for the hard-bottomed sections of a stream. During the non-breeding period of the year, the majority of specimens were captured in the swift, deeper waters, especially during the period from early November until late in March.

During the latter part of March and continuing through April, many individuals migrated from the swift waters to the shallower sections having a moderate current. The water temperatures through this period varied from 44°F. on April 13 to 58°F. on April 20 and 54°F. on April 22. While no nests were discovered on the date last mentioned, in several instances single pairs were captured, indicating that in this species the sexes were exhibiting interest in one another in advance of egg-laying.

In the nesting areas of the stream, the fan-tailed darter is found in association with the following species: the common shiner, *Notropis cornutus chrysocephalus;* the blunt-nosed minnow, *Hyborhynchus notatus;* the black-nosed dace, *Rhinichthys atronasus atronasus;* the long-nosed dace, *Rhinichthys cataractae,* and the creek chub, *Nocomis biguttatus*—among the minnows; the hog-sucker, *Hypentelium nigricans,* and the yellow stonecat, *Noturus flavus.* The spiny-rayed fishes were represented by a few young large-mouthed bass, *Aplites salmoides;* the common sunfish, *Eupomotis gibbosus;* the rock bass, *Ambloplites rupestris;* the johnny darter, *Boleosoma nigrum olmstedi;* the green-sided darter, *Etheostoma blennioides;* and the black-sided darter, *Hadropterus maculatus.* A single specimen of the young of the common bullhead, *Ameiurus nebulosus,* and a single mud minnow, *Umbra limi,* were also taken, both probably strays, as neither is typical of this kind of habitat.

Only one of these species was found breeding in this particular locality. A nest of *Hyborhynchus notatus,* containing about 1500 eggs and attended by the male, was found June 1. The very small eggs were attached to the lower surface of a large stone which rested on other stones of the bottom in such a way as to leave a space three-fourths of an inch beneath.

The green-sided and fan-tailed darters were found together in the swifter waters until in April, when the fan-tails moved to the breeding grounds. The green-sided darters remained in the riffles and more weedy places and were only rarely found in the nesting area occupied by the fan-tails. In the latter part of May, however, many green-sided darters were seen on the gravelly shoals, but no breeding activities were observed.

At no time were other species of fish discovered feeding upon the eggs of the fan-tailed darter, apparently because of their inaccessibility. Possibly the greatest enemies of the eggs were the smaller crayfish, which were very

abundant. Many nests were located from which the eggs disappeared before hatching, nothing remaining to indicate their former presence except the scars on the nest stone and a few tattered egg envelops.

Breeding Habits

Unlike many of its relatives among the darters, the colors of the fan-tail are quite dull, being of a dusky olive shade with darker blotches in irregular cross-bar pattern. In early spring the colors become more pronounced, and the male in particular grows darker, while the spines of the low first dorsal become swollen and tipped with orange. The females become heavy with ripe eggs about the middle of April. These have gradually developed through the period from late summer of the previous year. Dissection shows the ovaries to be free from eggs in late June and July, directly following the breeding season. By November the eggs are of considerable size. Observations at various times throughout the year indicate a progressive development until the middle of April, when the sides of the females bulge prominently with the greatly distended ovaries, the eggs showing clearly through the stretched membranes of the belly. Compared with the normal condition, the vent is swollen and protuberant.

Evidently the urge for mating is felt by the males slightly in advance of the females, for upon carefully searching the breeding grounds about April 20 the males were found pre-empting particular nesting sites. The sites were usually located in moderately moving water mostly above the riffles and in the shallower portions of the stream. A stone supported above the bottom approximately one-half to three-fourths of an inch but with very few places of possible entrance is selected for the nest. In fact, many of these slim creatures found it necessary in slipping through the narrow entrance to turn sideways and wriggle vigorously. The nest beneath the stone is a simple cavity and varies in size according to the space that can be utilized, its shape being determined by the disposition of the surrounding pebbles. All surfaces are evidently cleaned from sediment by the turning and wallowing movements of the body, the current carrying away the light material.

Having prepared the nest, the male impatiently awaits the female. Sometimes the female may be seen leisurely slipping from stone to stone, poking her head first under one, then another. When an awaiting male is approached, he eagerly starts forward from beneath his stone to meet her. A few turns about may be cautiously made but with seeming subdued excitement. Either the male or female may enter the nest first, and they may enter and leave several times before the female finally remains to spawn. While the fan-tail appears very cautious and stealthy in its movements, often during the breeding season one may slowly lift the nest-stone without frightening the fish away. When care was used, an observer could even extend the hand and touch the male with the finger before he would leave the nest.

Many efforts were made to discover what actually took place in the nest beneath the stone, but no satisfactory results were obtained on the breeding grounds. The principal difficulty encountered was in connection with the

female, which, as soon as the stone was disturbed, darted away and was never observed to come back to the same nest. Much time was spent in an endeavor to arrange a stone in a position to permit observation beneath by the aid of a small mirror placed at an angle of forty-five degrees. The shadow of the stone in contrast with the surrounding light and the inadvisability of raising the stone very far prevented successful observations. The distortion due to the moving surface of the water resulting from current and wind added to the difficulties. A glass bottomed bucket was immersed over the nesting site in an endeavor to solve this difficulty, but it was found too tiring to make extended observations in the position necessary. Some nests were found in water sufficiently shallow to allow good observation, other conditions permitting, but unfortunately no particular success was attained.

Because of these difficulties it was decided to carry on the study of the darters in confinement. Tanks were constructed and supported upon sawhorses. The water flowing out of the tanks was aerated, and when an auxiliary tub was full a float made an electrical contact starting a motor which pumped the water back into them. A small metal tube inserted into the tub outlet also helped to mix air with the water as it was pumped out. The water running from one side compartment of the large tank to the other maintained a constant, slowly moving current in which suitable flat stones were placed and partially surrounded by other smaller stones. At the end of the tank, away from the pump, a mirror was placed at an angle of forty-five degrees so that an observer could see beneath the nest stone. A board placed across the top served as a suitable shield to the sky light and also as a head rest. An excellent view of the under surface of the stone could easily be obtained since the field of vision was within a distance of about sixteen inches. The quicksilver of the mirror was protected from peeling by waterproofing the back with auto top-dressing.

The stream habitat of the fishes was duplicated as nearly as possible in the observation tank by the use of sand, gravel, and various water plants, together with organisms screened from the weeds and gravel of the creek. The advantages of this arrangement were several. Any number of ripe females and males could be placed in the compartment. Observations could be carried on over extended periods of time without in the least disturbing the activities of the fish, and the strain incident to long continued observations was in large part obviated.

Activities at the Nest Site

The darters transferred from the creek to the breeding tanks continued their activities, the change apparently being made without upsetting their natural proclivities. Various conditions were provided in the tank; e.g., in addition to the one nest stone, others were placed for shelter. The male invariably kept to the one stone that was in the current. Upon the approach of another darter the nesting male faced about and moved quickly toward it with a darting movement, but remaining either partially under or near the stone. If the fish attempted to enter, the male made quick thrusting move-

ments toward it, and if the invader were a male, actually bit at the fins or tail. If the approaching fish were a female, the thrusting movements were not vigorous but took on the character of prodding or bunting with the nose. This soon developed into various maneuverings beneath the stone, first one way then the other, the fish nosing and pushing one another about, each at times slipping the head beneath or over the body of the other.

The actual spawning positions and egg laying were observed to the best advantage and for the longest period on May 12 (Fig. 1). At this time the temperature of the water was 70°F. and that of the air 64°F. As the observations were begun (3:26 p.m.), the female was found belly upward against the lower surface of the stone and was creeping about with short jerky movements. The male nosed the female in the side, and both turned slowly about, circling first one way and then the other, the head of the male at the tail of the female. At the moment of deposition of the egg, the female applied her vent directly against the lower surface of the stone. The male only partially turned the fore part of the body but twisted the posterior part so that his vent was at the side of that of the female, the two fish still retaining the head-to-tail relationship. A tremulous movement was evident in both fish as egg and sperm were emitted simultaneously (3:27 p.m.). The position assumed by the male was held only momentarily, but the female retained her inverted position against the nest stone,—in one instance for two hours.

Following the deposition of the egg, both remained quiet for a few moments, then again began to move about, turning, rubbing, and nosing one another. Another egg was deposited and fertilized as described above, at 3:30 p.m. The regular sequence of events followed one another without great variation as follows: Rested quietly one-half a minute, moved about, nosed one another, and deposited an egg at 3:32 p.m.; rested about one-half of a minute, moved about, nosing and turning, and deposited an egg at 3:33½ p.m., rested, moved about, turning and nosing, and deposited three eggs in rapid sequence, with a bobbing movement evident in the female as she placed her vent against the stone and withdrew it, 3:35 p.m.

As indicated above, both fish exhibited a tremulous movement during the deposition and fertilization of the egg, and during the period when three eggs were being deposited in succession, the male retained the inverted position longer than usual. Another single egg was deposited at 3:38 p.m., following the usual movements. The process was repeated at intervals of one to three minutes, until finally the female suddenly turned, assumed the upright position, and darted out of the nest, the male following for a few inches. Forty-seven eggs were counted after this spawning, each deposited singly, except in the one instance noted above. The time from the first observation at 3:27 p.m. to the end of the spawning at 5:25 p.m. was almost exactly two hours, and averaged 2½ minutes for the deposition of each egg. The female concerned was captured and marked for later dissection.

Other spawnings were observed, but in no instance with so favorable results. From data obtained, however, it seems apparent that the females leave

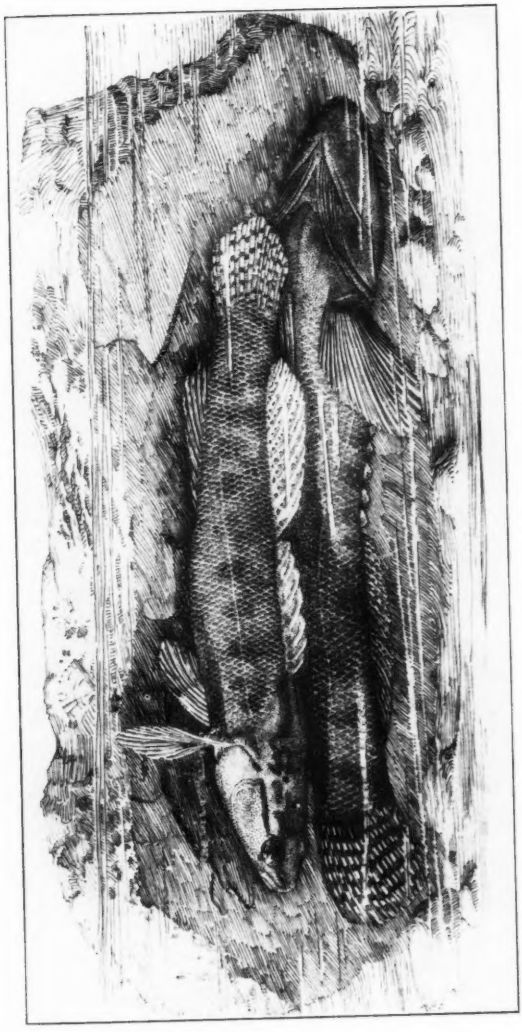


Fig. 1. The spawning positions in the nest.

the nest immediately or soon after spawning, and that only one female at a time succeeds in remaining in the nest to spawn.

During one observation, while one female was spawning, two other females were placed in the tank and guided under the nesting stone. Female No. 1 deposited an egg as the other two dashed beneath the stone and attracted the attention of the male. The male darted to female No. 2, poking her with his nose. Successive dashes and much chasing about followed on the part of females No. 2 and No. 3, without their leaving the nest, however. Female No. 1 tried to proceed with her spawning, moving about slowly but remaining in the inverted position. The male chased female No. 2 out of the nest (or at least she departed), and continued after female No. 3, the sand flying as they dashed about under the stone; finally she also left. The male next darted toward the original female, which still maintained the spawning position. This female appeared startled or else was ready to leave, for she darted out of the nest, turning over as she went. She was several times cautiously directed under the nesting stone by the aid of a stick, but the male refused to accept her. Females No. 2 and 3 were introduced under the nest-stone several additional times, only to be promptly chased out again.

On another occasion, other individuals were under observation late in the afternoon. At this time the female was seen lying quietly on the bottom beneath the nest-stone. The male swam around her, slowly bunting her with his nose and finally placed his chin over her head for a moment. While in this position, another female came into the nest. At first the male did not appear disposed to drive her out. He moved toward her slowly, then darted quickly, causing her to dash around in a circle. The male darted at her again, and she rushed around the nest but did not leave. This occurred several times, resulting finally in her retreat. The first female remained quiet during this procedure, after which the male again devoted his attention to her as described. Further observations were prevented by darkness.

The following behavior was observed on June 15 at a nest located in six inches of water on the breeding grounds. Small stones one-half of an inch thick were cautiously placed under three corners of the nest-stone. A mirror was then placed in such a position that one could see under the stone by kneeling down over it. A dead male darter skewered upon a fairly stiff wire was introduced. The nesting male fought it, taking hold of a pectoral fin with his mouth and shaking violently. The dead darter was then withdrawn in a retreating manner, the male following and darting at it until it was 15 inches away, when the male returned to the nest. The dead darter was agained moved toward the nest in life-like manner, and when the male appeared at the edge of the nest it was withdrawn quickly. The nesting male attacked fiercely, taking hold of the tail. This process was repeated several times with similar results. Next, a female was introduced on a wire. The male poked it several times with his nose, but by moving the female slightly in a jerky fashion and poking the side of the male gently with its nose, the male was induced to allow it to remain. The female was then withdrawn and introduced again in an inverted, spawning position. The male

accepted it readily without any attempt to bite or attack. The dead female was then moved around in a slightly jerky manner, simulating as nearly as possible the natural movement of a living female. After much patience and manipulation, the male was induced to perform the spawning act several times with the dead female. The dead male was next introduced in an inverted position. The nesting male moving about in a normal manner allowed it to remain and made no effort to drive it out; but no other behavior was induced.

From the actual record of fifty-five marked nests observed throughout the breeding season, and thirty-six other nests examined during the afternoon of May 18, together with all observations not of a systematic character, it was found that the male exercised the only parental care that the eggs received. Almost without exception the male was present in the nest. Those cases when the male was not found could be accounted for by the observor's inability to see clearly and the possibility that adjacent cover hid the disturbed male. No particular manipulation or marked care of the eggs by the male was ever noticed other than his constant presence.* The conclusion was reached that his restless movements, clearly evident, served the purpose of keeping the eggs constantly brushed by his dorsal fins. The space available beneath the stone made this result not only possible but unavoidable. Under stream conditions, experiments indicated that, in the absence of the male, the eggs quickly became fungused. When the eggs were agitated by a constant current of water through a large test tube, causing the mass of eggs to move against one another, development continued for a time.

The location of the nests on the breeding grounds is determined in part by the chance distribution of suitable stones. It was found that rarely was one nest nearer than four feet to another. In one case two nests were found within 18 inches of each other, while in another case, within 12 inches. In a third case two nests were found beneath a stone which measured about eight by twelve inches, one nest under each end but the two not connected in any way. As the stone was lifted, about 150 eggs were seen in each of two distinct groups corresponding to the two depressions in the creek bottom. The males could easily be distinguished, because one was much darker than the other. A fight between them ensued, during which each darted at the other, then rushed back to its own nest. The stone was replaced, and upon examining the nests five days later it was found that the eggs belonging to the darker male had all hatched. When the stone was lifted a fight again followed, and this resulted in the dark male being driven away, perhaps because he had no eggs to defend. Four days later new eggs were found in the nest of the lighter colored male. This same nest was under further observation for 17 days until the end of the season, but the other one remained empty.

* A considerable number of males in the b eeding season developed a conspicuous pigmented spot at the point of the chin. Many of the older males had the tissues at this point worn away, exposing the teeth and sometimes the naked mandibles. This gave the projecting lower jaw a ferocious bull-dog-like appearance.

Number of Spawnings and Eggs

From the breeding behavior described above and from the spawning positions assumed by the darters, it appears evident that the male spawns with but one female at a time. That several females may spawn in the same nest successively is also evident from the following considerations. By actual count the number of eggs found in a single nest varies from eight or ten to 562, the largest number encountered (Fig. 2). The variation in the number of eggs found in different nests depends upon several factors. First, the

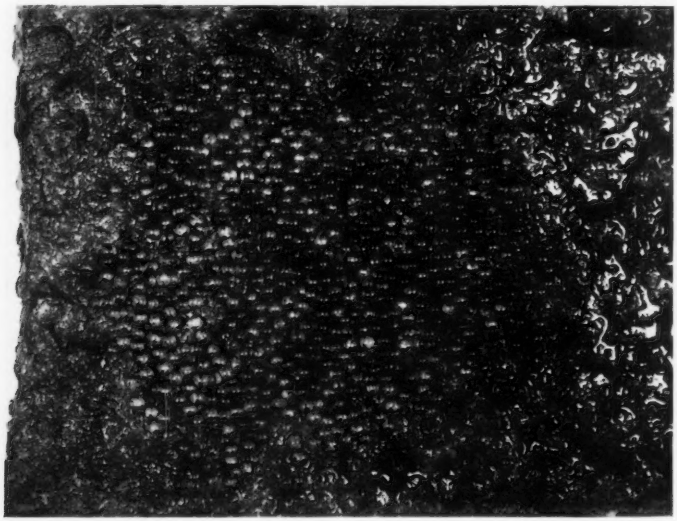


Fig. 2. The largest nest discovered, containing 562 eggs. Natural size.

amount of space available beneath the stone; second, the size of the parent female, dissection having shown that smaller individuals develop fewer eggs; third, the number of spawnings which have occurred. Observations made upon marked nests toward the end of the breeding season showed that the eggs hatched in batches of approximately 45 eggs each. Eighty-one nests averaged 168.8 eggs each. If the average number spawned at one time is about 45, as was actually observed in one instance in the breeding tank, each nest would contain an average of about four spawnings. As a matter of fact, dissection of 23 of the larger females showed an average of 226.2 eggs in the ovaries, disposed in five rather definite size groups. This would indicate an average of 45 eggs in each of five spawnings for the larger fish. If both large and small females are taken into account, and if the eggs are spawned in five lots, as is believed, a general average of 33.76 eggs per female per spawning is obtained.

Dissection of 23 mature darters collected April 24, 1935, indicate, as previously stated, an average of 226.2 eggs. These vary from 128 eggs in a female of 33 mm. standard length to 422 eggs in a female of 49 mm. In all cases, however, the eggs in each ovary showed distinct differences in size, indicating different degrees of maturity. In order to determine the number of eggs in each group, those clearly ready to be deposited were counted and designated as group 1, those definitely yellow and decidedly smaller were designated as group 2, while in group 3 were placed all remaining eggs, regardless of size; then the number in group 3 was divided by the average number in the first two groups. The nearest whole number obtained, with few exceptions, was the number three. Thus it would seem that the fan-tail darters spawn about five times during the breeding season.

This conclusion is supported by the dissection of females known to have spawned one or more times. Such dissections showed that all eggs had not been deposited and that the smallest ones remained. Again, after the breeding season was entirely past, dissection proved that all eggs had been laid and that none remained to be carried over to the following year. After averaging the eggs of group 1 and obtaining the number 49, and after observing in two instances that 47 eggs were laid at a single spawning, we feel confident that approximately 45 eggs are laid at one spawning by the larger females, especially since this is the average of the total number of dissected eggs divided by five.

The diameter of each mature egg averages 2.3 mm., a figure obtained by measuring 166 eggs taken from three representative nests.

Development of Young

Unfavorable weather and flood conditions in the creek made it seem for a time impossible to determine the length of the incubation period. The conditions that at first appeared so unpropitious, proved later, however, to be of great advantage. On April 26 the first nest of the breeding season was discovered. It contained 65 eggs. The temperature of the water was 63°F. A diligent search that day revealed no other nests. Fair weather followed for a few days, during which on April 27 and April 29 quite a number of nests were located and marked by attaching numbered paraffined tags to adjacent stones. Following this, a period of stormy and cold weather set in on May 2 and lasted until May 8. The creek overflowed its banks and was so swift and roily that observations were impossible until after May 11. On that date, although it was still high and roily, a few fan-tails were taken in the margin of the stream. This unfavorable weather prevented general spawning until the water subsided and cleared of sediment during a period of warm weather which followed. On May 15 it was possible to wade on the breeding grounds. On May 18, 36 nests were discovered. This fixes the height of the spawning period definitely at about May 15; and as the eggs in these nests were hatching when an inspection was made on June 5, the incubation period was about 21 days.

From the records of 55 marked nests it was found that at the beginning

of the spawning season, during the latter part of April, the incubation period extended from 30 to 35 days, with water temperatures ranging from 63°F. to 68°F. Eggs laid May 15 to May 18 hatched in 21 days, the water temperatures during the latter part averaging about 70°F.-71°F. Eggs laid June 1 to 5 hatched in 14 to 16 days, the average temperature then being 74°F. Our records show that eggs were deposited during the period from April 26 to June 5, with the bulk spawned about May 15. Eggs in different nests hatched from May 27 to June 22, the majority of them by June 5.

One nest, No. 19 supplied the following record: "April 29; water 63°F; air 65°F; nest beneath a 4 by 6 inch roughly triangular stone; about 100 eggs; male present. He moved away about one foot as stone was raised; returned cautiously to nest and remained, as stone was replaced. May 1, water 50°F; air 44°F. Male present. Eggs about 250 to 300. Male remained in nest as stone was lifted on edge; finally moved about one foot away but came back slowly in about one-half minute, and remained, as stone was replaced. May 15, male present. Water 50°F. Took up nest and placed it in breeding trough in running water, the temperature of which was uniformly cold, ranging from 50°F. to 55°F. This lot hatched June 13, 14, and 15, except 31 eggs, making an incubation period of 48 days at a low temperature." This evidently correlates the incubation period with the temperature of the water.

Dispersal of Young and Early Development

The young darters are very active as soon as they are hatched and remain quiet only for very short intervals of time. True to their name, they dart upward, wriggling vigorously, then stop and settle to the bottom. Because of their comparatively heavy yolk sac they seldom swim in a straight line; yet they soon find their way out of the nest. Due to their activity and also to the current they are rapidly dispersed among the stones and weeds of the bottom. Careful search in and around a nest where hatching had recently occurred usually failed to disclose any of the young darters. Their slightly streaked pattern and transparency effectually conceal them against the background of the creek bottom. By using a small cheesecloth dip-net, however, and stirring the gravelly bottom with the hand, quite a number of the recently-hatched young were obtained.

Young in considerable numbers were secured by transferring to glass containers nests containing embryos about ready to hatch. Fungus apparently does not attack the eggs after the embryos begin to wriggle within the envelopes. When they break through the surrounding envelopes their average length is 7 mm. The yolk-sac is absorbed in 7 to 10 days, during which period very little increase in length is evident. The principal changes that occur during this period are as follows: the eyes become more normal in appearance and position; the fins take on definite form, and the spines and rays becomes evident; the head and skeletal features develop; and the internal organs of the alimentary tract take on more definite form. These changing features, as well as the entire circulatory system, can be seen with the binocular microscope through the transparent tissues (Fig. 3).

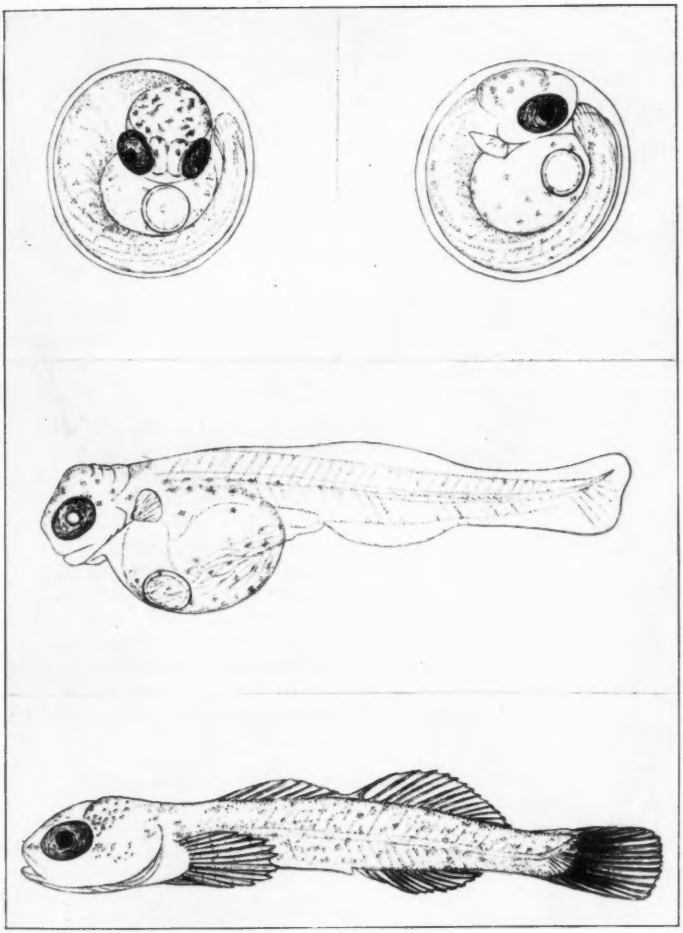


Fig. 3. Development of young. Upper drawings, about to hatch. Middle drawing, just emerged. Lower, yolk-sac absorbed.

Growth Rate and Age

The difficulty of keeping young fan-tail darters in captivity and of maintaining a normal food supply led to the placing of a number of them in the creek, within a wire basket of fine mesh. No doubt this method of rearing them would have proved successful had not a succession of storms and cloudbursts passed over the state and flooded the streams. This experiment having failed, the expedient of seining with a fine cheese-cloth net was resorted to at twelve intervals during the summer and fall months in order to secure material for a study of the growth rate. It was assumed that all eggs had hatched by June 25, and that measurement of the twelve smallest darters of each seining would give fairly accurate data on the growth of the young. From the figures obtained, the growth-rate from hatching in June to November was secured, indicating a gradual increase in size up to about 30 mm.

To determine the age attained by this species and the growth-rate to maturity, specimens of all sizes were collected during November and December and again in early April. A graph was constructed based on the measurements of 423 females, employing 2 mm. class intervals.

When November and December specimens only were considered, two definite and fairly regular modes were apparent. When the measurments of April specimens were added, the modes were still more prominent; but the first showed a slight break, not accounted for, opposite the 28 mm. group.

The dissection of the young females of the year (about 30 mm. long), collected in November, showed no ripening eggs; but females of the same size taken in April contained a small number of well-developed eggs. The larger females taken in November, which had spawned earlier in the year, all had developing eggs in considerable numbers. From these considerations it seems apparent that the female fan-tailed darters reach sexual maturity and spawn during the spring of the year following that of hatching and again the year after. Dissection of males showed that they, too, reached sexual maturity in the same length of time.

The graph showed a prominent mode at 34 mm. and another at 42 mm., when females alone are considered. When specimens of both sexes were taken into account, it was found that the females outnumbered the males in the proportion of 520 to 228. Since these specimens were taken outside the nesting season, when there is no evidence of segregation, the numbers probably approximate the actual proportions. The lengths of the males when plotted in 2 mm. class intervals did not give the definite modes apparent in the graphs of the female, perhaps because an insufficient number was available. The measurements indicate, however, that the males attain a larger average size. The largest female found on the breeding grounds measured 51 mm. standard length, the largest male 61 mm. In Northrup Creek a male 70 mm. long was taken.

Conclusions

From this study the following conclusions have been drawn:

1. During the greater part of the year, the fan-tailed darter prefers the swifter waters of the stony and gravelly riffles, but seeks the shallow, moderately moving waters for the spawning season.

2. The nest is selected and prepared by the male beneath a stone, where he constantly attends the eggs.

3. Although usually elusive and shy, the fan-tailed darters during the breeding season are easily approached. Often the male may be touched with the extended finger before he will desert the nest.

4. The egg-laying season and period of incubation in the latitude of Rochester, New York extends from April 26 to June 22.

5. The eggs are deposited and fertilized singly and attached to the lower surface of the stone which serves as the shelter for the nest.

6. The female when spawning may remain in the inverted position until the entire complement of ripe eggs has been deposited, a period of about two hours.

7. The male usually assumes the inverted position only at the moment of deposition of an egg.

8. The females leaves the nest soon after her complement of eggs has been deposited.

9. Several females may spawn successively in the same nest.

10. A large female may spawn five times during the egg-laying season, depositing, on the average, about forty-five eggs each time.

11. Dissection of females taken immediately after the spawning season shows that eggs are not carried over to the following year.

12. The average diameter of the eggs is 2.3 mm.

13. There is a fairly close correlation between stream temperature and the length of the period of incubation; at 70°F. the incubation period covers about 21 days.

14. Sexual maturity is attained the spring of the year following hatching, the female apparently spawning in two successive years.

15. The females apparently greatly outnumber the males, the proportion being greater than two to one.

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Food Habits of Marsh Hawks in the Glaciated Prairie Region of North-Central United States*

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Both authors have for some years been interested in the correlation of the food habits of the marsh hawk *(Circus hudsonius* (Linn.)) with the availability of prey species and have, with this objective in mind, carried on studies in different types of North-Central States environment. The need was felt especially for data of recent origin secured from areas with which one author or the other was intimately familiar. The literature, therefore, has been of limited help to us except in a general way, and we have relied primarily upon the products of our own joint or separate investigations.

Errington's ('33a; '33b) earlier work in Southern Wisconsin was conducted in connection with an ecological study of the bob-white quail *(Colinus virginianus)*, and the population status of this species on the observational areas was well known. Data on other animal populations resident on the marsh hawk hunting grounds were acquired incidentally and were recorded more on the basis of general impressions than upon actual measurements.

The detailed studies of Breckenridge ('34; '35) on a sample square mile of land in Central Minnesota were planned more as an inquiry into the ecological inter-relationships of the marsh hawk and the chief vertebrate co-occupants of a local area. Population levels of mammals were calculated by trapping and those of birds by census (Breckenridge, '35a). Contemporaneous studies on the food habits of other predatory species, notably the great horned owl *(Bubo virginianus)*, on the same area, provided additional data on the comparative vulnerability of small vertebrate types taken also by marsh hawks (Errington *et al.*, unpublished MS.).

This paper deals with data derived from the glaciated prairie agricultural region, topographically represented by Northwestern Iowa, Southwestern Minnesota, and Eastern South Dakota. The land is gently rolling and largely in cultivation, with unpastured acreage usually in corn, oats, barley, and alfalfa. Lakes and marshes are distributed here and there, though many have been drained or dried up by drought. Swales or other low places grown to dense herbaceous or brushy vegetation are of frequent occurrence. Trees are confined mainly to planted groves or to the borders of watercourses.

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Our summer data are by far the most complete and resulted for the most part from intensive studies near Ruthven, Iowa, during three seasons from 1933 to 1935. Emphasis was placed on the recording of food items brought in to nests and to tethered juveniles ("tethering" refers to the fastening of active juveniles in the vicinity of the nests by means of chains and leather anklets—for description of technique, see Errington, '32, pp. 82-83).

Examinations of the gullet contents of the juveniles were productive of superior data, for, by judicious squeezing (Errington, '32, pp. 78-79), the young hawks could be relieved, without injury to themselves, of the food fed them by the attending adults. Gullet contents from nestlings or tethered juveniles could often be collected once or twice daily. In case the suspicion arose that a young bird was being robbed of too much of its food or was not getting enough to eat, it was force-fed at the end of each visit. In this way, visits could be prolonged far past the time that the young would have left their nests, until the adults no longer brought food. The young, then, if they had survived the various perils of disease, parasites, predators, man, and heat, were banded and released.

Gullet contents are as a rule identifiable and provide a good cross-section of the foods brought to young marsh hawks by the parent birds. They may provide a picture more truly applicable, however, to the food habits of the adults than to the food habits of the young after the latter have left the nest. The clumsy, inexperienced juveniles, when hunting partly "on their own" in a normal manner during the gradual tapering off of feeding or "weaning" by adults, feed to a considerable extent on carrion, large insects, and other items which are not so apt to be brought to them by the old birds. The adults, moreover, while they catch and eat insects themselves, rarely if ever take the trouble to carry them to the young.

At Ruthven the collection and analyses of the gullet contents and the prey items were made mostly by Mr. and Mrs. F. N. Hamerstrom Jr., Miss Ruth Dudgeon, and Errington. Identification of prey items was accomplished with the aid of a fairly adequate reference series of skins and skeletons of locally resident mammals and birds. The greatest effort was made to obtain food habits data of quantitative rather than qualitative significance, and, with this end in view, the gullet contents of all nestlings or tethered juveniles of a hawk family were combined at each visit and the mass then worked over to determine if possible the minimum number of individuals of prey represented by the collection.

While many of the prey species of the area were observed in an incidental way, many others, especially some of economic importance, were made the subjects of intensive research for at least part of the period covered by the marsh hawk studies. These included ducks (Bennett, '32; '35a; Errington and Bennett, '34; B. V. Travis, unpublished), marsh-nesting birds, generally (Bennett, '34), coots and grebes (C. E. Friley Jr., unpublished), shorebirds (Bennett, '35b; Spawn, '35), ring-necked pheasant (Hamerstrom, '35; '36). blackbirds (Ammann, '33), muskrat (Errington, unpublished). We also

have unpublished data on the Hungarian partridge and some other common species from this area, and we did a certain amount of small mammal trapping.

It should be pointed out, however, that despite much work done by several investigators on the area which comprised the hunting ranges of the local marsh hawks, we have few population data on prey species that may be expressed with numerical exactness and still fewer that may be correlated with any precisely known carrying capacity of occupied environment. Nevertheless, we know what the chief terrestrial vertebrates were; and, in a broad way, about how abundant they were and about how available to a predatory species having the physical powers and habits of the Marsh Hawk.

The Ruthven data may best be presented by seasons.

Summer, 1933

Rainfall was favorable for plant growth and for the fair maintenance of established water levels in the marshes. The season could probably be termed "normal" in most respects.

A total of 289 individuals of prey were recorded from 169 gullet collections between June 17 and August 25. The data from four nests may be lumped according to weekly intervals.

WEEK OF JUNE 17 TO 23: Twenty-four gullet collections. Contents, in individuals of prey: young cottontail *(Sylvilagus floridanus mearnsi)*, 1; meadow mouse *(Microtus* sp.), 1; adult and young striped ground squirrel *(Citellus tridecemlineatus)*, 22; young Fringillidae, 1; undetermined small bird (incl. 1 young), 3.

WEEK OF JUNE 24 TO 30: Twenty-five gullet collections. Contents: young cottontail, 1; Franklin's ground squirrel *(Citellus franklini)*, incl. 3 young, 4; striped ground squirrel (mostly young), 26; young undetermined ground squirrel, 1; grasshopper sparrow *(Ammodramus savannarum bimaculatus)*, 1; yellow-headed blackbird *(Xanthocephalus xanthocephalus*, incl. 1 young), 3; English sparrow *(Passer domesticus)*, 1; prairie horned lark *(Otocoris alpestris praticola)*, 2; young red-headed woodpecker *(Melanerpes erythrocephalus)*, 1.

WEEK OF JULY 1 TO 7: Twenty-eight gullet collections. Contents: young cottontail, 1; meadow mouse, 1; deer mouse *(Peromyscus* sp), 1; young Franklin's ground squirrel, 1; striped ground squirrel (mostly young), 30; Fringillidae, 1; young yellow-headed blackbird, 1; young meadowlark *(Sturnella* sp.), 3; undetermined Icteridae, 1; young wren *(Troglodytidae)*, 1; kingbird *(Tyrannus tyrannus)*, 1; undetermined young small birds, probably passerines, 3; very young sora *(Porzana carolina)*, 1; young (about 6 weeks) ring-necked pheasant *(Phasianus colchicus torquatus)*, 2; young (chick) Hungarian partridge *(Perdix perdix)*, 1; duckling, probably blue-winged teal *(Querquedula discors)*, 1; frog *(Rana* sp.), 1.

WEEK OF JULY 8 TO 14: Nineteen gullet collections. Contents: young Leporidae, 1; young Franklin's ground squirrel, 1; striped ground squirrel (incl. young of adult sizes), 15; swamp sparrow *(Melospiza georgiana)*, 1; meadowlark, 2; undetermined passerine bird, 1; red-headed woodpecker, 1; flicker *(Colaptes auratus luteus)*, 1; young Forster's tern *(Sterna forsteri)*, 1; undetermined shore bird (Charadrioidea), 1; young domestic chicken *(Gallus)*, 2; young (about 3, 5 and 7 weeks) ring-necked pheasants, 3; undetermined young gallinaceous bird, 1; undetermined small bird, 1.

WEEK OF JULY 15 TO 21: Eleven gullet collections. Contents: young jack rabbit *(Lepus townsendii campanius)*, 2; young Franklins ground squirrel, 1; striped ground squirrel, 5; young Fringillidae, 1; grackle *(Quiscalus quiscula aeneus)*, 1; young (4 weeks) pheasant, 1; undetermined young gallinaceous bird, 1.

WEEK OF JULY 22 TO 28: Nineteen gullet collections. Contents: young cottontail, 1; young jack rabbit, 1; young Leporidae, 1; young Franklin's ground squirrel, 5; striped ground squirrel, 7; savannah sparrow *(Passerculus sandwichensis savanna)*, 1; grackle, 2; meadowlark, 2; robin *(Turdus migratorius)*, 1; flicker, 5; mourning dove *(Zenaidura macroura*, probably *carolinensis)*, 1; young Virginia rail *(Rallus limicola)*, 1; young domestic chicken, 5; young Hungarian partridge, 1;young medium-sized bird, probably gallinaceous, 1; undetermined small bird, 2; frog, 2.

WEEK OF JULY 29 TO AUGUST 4: Ten Gullet collections. Contents: young cottontail, 1; Franklin's ground squirrel, 2; striped ground squirrel, 4; grackle, 3; meadowlark, 1; flicker, 5; young mourning dove, 1; young (about 2, 6, 9, and 10 weeks) pheasants, 4.

WEEK OF AUGUST 5 TO 11: Thirteen gullet collections. Contents: striped ground squirrel, 4; grackle, 2; red-winged blackbird *(Agelaius phoeniceus)*, 6; yellow-headed blackbird, 6; flicker, 2; mourning dove, 1; Virginia rail, 1; young (about 10 weeks) pheasant, 1; nearly grown Hungarian partridge, 1; frog, 1.

WEEK OF AUGUST 12 TO 18: Fourteen gullet collections. Contents: young cottontail, 2; striped ground squirrel, 4; grackle, 3; red-winged blackbird, 5; yellow-headed blackbird, 7; undetermined passerine bird, 1; red-headed woodpecker, 1; young screech owl *(Otus asio)*, 2; young mourning dove, 1; Virginia rail, 1; young (about 7 weeks) pheasant, 1; Hungarian partridge, 1; frog, 3.

WEEK OF AUGUST 19 TO 25: Six gullet collections. Contents: striped ground squirrel, 2; yellow-headed blackbird, 2; meadowlark, 1; young screech owl, 1; Hungarian partridge, 1; frog, 1.

Summer, 1934

This was a season of extreme early drought, accompanied by scanty growth of vegetation, excessive pasturing, and unfavorable conditions for wildlife, generally. Vegetation recovered somewhat with mid-summer rains, but much of the best remaining habitat for many species was flooded out. Many unseasonably late young birds were seen.

One hundred nine gullet collections from 4 nests yielded 158 individuals of prey.

WEEK OF JUNE 17 TO 23: One gullet collection. Content: undetermined small bird, probably Icteridae, 1.

WEEK OF JUNE 24 TO 30: Eight collections. Contents: young Leporidae, 1; young striped ground squirrel, 2; young undetermined ground squirrel, 2; Fringillidae, 1; young yellow-headed blackbird, 1; young Rallidae, 1; undetermined small bird, 1; frog, 1.

WEEK OF JULY 1 TO 7: Eight gullet collections. Contents: young cottontail, 2; young Franklin's ground squirrel, 2; striped ground squirrel, 6; young yellow-headed blackbird, 1; young meadowlark, 1; undetermined vertebrate, 1.

WEEK OF JULY 8 TO 14: Six gullet collections. Contents: young Franklin's

ground squirrel, 1; striped ground squirrel (mostly young), 4; undetermined young ground squirrel, 1; young yellow-headed blackbird, 1; frog, 1.

WEEK OF JULY 15 TO 21: Four gullet collections. Contents: young striped ground squirrel, 1; young Fringillidae, 1; young yellow-headed blackbird, 2.

WEEK OF JULY 22 TO 28: Eight gullet collections. Contents: striped ground squirrel, 6; Fringillidae, 2; flicker, 1; young tern, probably Forster's, 1.

WEEK OF JULY 29 TO AUGUST 4: Twenty gullet collections. Contents: meadow mouse, 2; striped ground squirrel, 3; undetermined young ground squirrel, 1; swamp sparrow, 1; meadow-lark, 1; bobolink *(Dolichonyx oryzivorus)*, 1; young Icteridae, 5; red-headed woodpecker, 1; flicker, 1; mourning dove (incl. 1 young), 2; young domestic chicken, 1; young (incl. individuals from about 4 to 6 weeks) pheasant, 5; Hungarian partridge, 1; undetermined young bird, 3; frog, 1.

WEEK OF AUGUST 5 TO 11: Twenty-one gullet collections. Contents: meadow mouse, 3; striped ground squirrel, 1; red-winged blackbird, 3; yellow-headed blackbird, 3; young meadow-lark, 1; undetermined Icteridae, 1; undetermined small bird, probably passerine, 1; flicker, 1; mourning dove, 4; young domestic chicken, 3; young (about 6 and 12 weeks) pheasant, 2; young Hungarian partridge, 1; undetermined young bird, 3; frog, 1; undetermined vertebrate, 1.

WEEK OF AUGUST 12 TO 18: Three gullet collections. Contents: undetermined ground squirrel, 1; grasshopper sparrow, 1; undetermined Fringillidae, 1; young meadowlark, 1; undetermined Icteridae, 1; young mourning dove, 1; half-grown domestic chicken, 2.

WEEK OF AUGUST 19 TO 25: Seven gullet collections. Contents: meadow mouse, 1; young Franklin's ground squirrel, 1; striped ground squirrel, 1; young Leconte's sparrow *(Passer herbulus caudacutus)*, 1; young Fringilidae, 2; meadowlark, 2; prairie marsh wren *(Telmatodytes pallustris dissaeptus)*, 1; king rail *(Rallus elegans)*, 1; young (about 9 weeks) pheasant, 1.

WEEK OF AUGUST 26 *to* SEPTEMBER 1: Fourteen gullet collections. Contents: young cottontail, 2; young Leporidae, 1; meadow mouse, 2; striped ground squirrel, 5; undetermined ground squirrel, 1; vesper sparrow *(Pooecetes gramineus)*, 2; Fringillidae, 2; meadowlark, 1; prairie marsh wren, 1; flicker, 2; young Virginia rail, 1; undetermined young fairly large and medium-sized birds, 2.

WEEK OF SEPTEMBER 2 TO 8: Eight gullet collections. Contents: young Leporidae, 1; meadow mouse, 2; striped ground squirrel, 2; vesper sparrow, 1; Fringillidae, 1; meadowlark, 2; Virginia rail, 2; sora 2.

SEPTEMBER 10: One gullet collection. Content: Virginia rail, 1.

Summer, 1935

This season the rainfall was heavy and the vegetation lush. Breeding conditions for resident wild species were generally favorable.

Records of 110 individuals of prey were obtained from 68 gullet collections from 4 nests.

TABLE 1

Weekly representation of summer prey types taken by Marsh Hawks at Ruthven, Iowa.

WEEK	June 17 to 23			June 24 to 30			July 1 to 7			July 8 to 14			July 15 to 21			July 22 to 28		
SEASON	'33	'34	'35	'33	'34	'35	'33	'34	'35	'33	'34	'35	'33	'34	'35	'33	'34	'35
Number of gullet collections	24	1		25	8	2	28	8	18	19	6	20	11	4	17	19	8	8
Sciuridae	22			31	4	2	31	8	19	16	6	9	6	1	3	12	6	
Grackles and blackbirds				3	1		1	1			1		1	2	2	2		
Young Leporidae	1			1	1		1	2		1		3	2		8	3		9
Meadowlarks and miscellaneous Icteridae							4	1	3	2		5			2	2		
Fringillidae	1			1	1		1		3	1		2	1	1	5	1	2	4
Miscellaneous and undetermined birds, mostly passerines	3	1		1	1		3			2		1	1			3		
Picidae, mostly flickers				1						2		1				5	1	1
Young ring-necked pheasants							2			3		1	1		2			1
Miscellaneous passerine birds				3			2			1		2			3	1		1
Frogs					1		1		1		1	1				2		2
Mice	1					1	2											2
Rallidae, mostly rails					1		1					1				1		
Young domestic chickens										2						5		
Mourning doves																1		
Hungarian partridge, mostly young							1		2							1		
Miscellaneous Marsh Birds, mostly terns							1		1	2		2					1	1
Undetermined or probable mammal								1				1						

TABLE 1 (Continued)

Weekly representation of summer prey types taken by Marsh Hawks at Ruthven, Iowa.

WEEK	July 29 to August 4			August 5 to 11			August 12 to 18			August 19 to 25			August 26 to September 1			September 2 to 10		
SEASON	'33	'34	'35	'33	'34	'35	'33	'34	'35	'33	'34	'35	'33	'34	'35	'33	'34	'35
Number of gullet collections	10	20	3	13	21		14	3		6	7			14			9	
Sciuridae	6	4	2	4	1		4	1		2	2			6			2	
Grackles and blackbirds	3			14	6		15			2								
Young Leporidae	1		1				2							3			1	
Meadowlarks and miscellaneous Icteridae	1	7			2			2		1	2			1			2	
Fringillidae		1						2			3			4			2	
Miscellaneous and undetermined birds, mostly passerines		3			4		2			1				2				
Picidae, mostly flickers	5	2		2	1		1							2				
Young ring-necked pheasants	4	5		1	2		1				1							
Miscellaneous passerine birds							1				1			1				
Frogs		1		1	1		3			1								
Mice		2			3						1			2			2	
Rallidae, mostly rails				1			1				1			1			5	
Young domestic chickens		1			3			2										
Mourning doves	1	2		1	4		1	1										
Hungarian partridge, mostly young		1		1	1		1			1								
Miscellaneous Marsh Birds, mostly terns																		
Undetermined or probable mammal					1													

TABLE 2

Proportions of summer prey taken by Marsh Hawks at Ruthven, Iowa.

Prey Individuals	Number and Percent of Total			
	June to August 1933	June to Sept. 1934	Mainly for July 1935	Three seasons 1933 to 1935
Young Leporidae, mostly cottontails with a few jackrabbits.	12 of 289 or 4.15 percent	7 of 158 or 4.43 percent	21 of 110 or 19.09 percent	40 of 557 or 7.18 percent
Mice, mostly meadow mice.	3 or 1.04 pct.	9 or 5.7 pct.	3 or 2.73 pct.	15 or 2.67 pct.
Sciuridae, mostly ground squirrels.	134 or 46.37 pct.	41 or 25.95 pct.	35 or 31.82 pct.	210 or 37.7 pct.
Undetermined mammal or probable mammal.		2 or 1.27 pct.	1 or 0.9 pct.	3 or 0.54 pct.
Fringillidae	6 or 2.08 pct.	16 or 10.13 pct.	14 or 12.73 pct.	36 or 6.46 pct.
Grackles and blackbirds.	41 or 14.19 pct.	11 or 6.96 pct.	2 or 1.82 pct.	54 or 9.7 pct.
Meadowlarks and a few other Icteridae.	10 or 3.46 pct.	17 or 10.76 pct.	10 or 9.09 pct.	37 or 6.64 pct.
Miscellaneous passerine birds.	8 or 2.77 pct.	2 or 1.27 pct.	6 or 5.45 pct.	16 or 2.87 pct.
Picidae, mostly flickers.	17 or 5.88 pct.	6 or 3.79 pct.	2 or 1.82 pct.	25 or 4.49 pct.
Mourning doves.	4 or 1.38 pct.	7 or 4.43 pct.		11 or 1.96 pct.
Rallidae, mostly Virginia rails and sora.	4 or 1.38 pct.	8 or 5.06 pct.	1 or 0.9 pct.	13 or 2.33 pct.
Miscellaneous marsh birds, mostly terns.	3 or 1.04 pct.	1 or 0.63 pct.	4 or 3.64 pct.	8 or 1.44 pct.
Young domestic chickens.	7 or 2.42 pct.	6 or 3.79 pct.		13 or 2.33 pct.
Young ring-necked pheasants.	12 or 4.15 pct.	8 or 5.06 pct.	4 or 3.64 pct.	24 or 4.31 pct.
Hungarian partridges, mostly young.	5 or 1.73 pct.	2 or 1.27 pct.	2 or 1.82 pct.	9 or 1.62 pct.
Miscellaneous and undetermined birds, mostly probable passerines.	15 or 5.19 pct.	11 or 6.96 pct.	1 or 0.9 pct.	27 or 4.85 pct.
Frogs	8 or 2.77 pct.	4 or 2.53 pct.	4 or 3.64 pct.	16 or 2.87 pct.

WEEK OF JUNE 24 TO 30: Two gullet collections. Contents: house mouse *(Mus musculus)*, 1; striped ground squirrel, 2.

WEEK OF JULY 1 TO 7: Eighteen gullet collections. Contents: young Franklin's ground squirrel, 4; striped ground squirrel (mostly young), 14; undetermined young ground squirrel, 1; Fringillidae (incl. 2 young), 3; young meadowlark, 3; young Forster's tern, 1; young Hungarian partridge, 2; frog, 1.

WEEK OF JULY 8 TO 14: Twenty gullet collections. Contents: young Leporidae, 3; young Franklin's ground squirrel, 2; striped ground squirrel, 7; undetermined small mammal, 1; dickcissel *(Spiza americana)*, 1; Fringillidae, 1; meadowlark (incl. at

least 3 young), 5; bank swallow *(Riparia riparia)*, 1; young prairie horned lark, 1; young red-headed woodpecker, 1; black tern *(Chlidonias nigra surinamensis)*, 2; young Virginia rail, 1; pheasant chick (about a day old), 1; undetermined small bird, 1; frog, 1.

WEEK OF JULY 15 TO 21: Seventeen gullet collections. Contents: young cottontail, 6; young jackrabbit, 1; young Leporidae, 1; young Franklin's ground squirrel, 1; striped ground squirrel, 2; grasshopper sparrow, 1; dickcissel, 1; young rose-breasted grosbeak *(Hedymeles ludovicianus)*, 1; Fringillidae, 2; red-winged blackbird, 2; meadowlark, 2; northern yellow-throat *(Geothlypis trichas brachidactyla)*, 1; young barn swallow *(Hirundo erythrogaster)*, 1; young prairie horned lark, 1; young (about 6 and 7 weeks) pheasant, 2.

WEEK OF JULY 22 TO 28: Eight gullet collections. Contents: young cottontail, 4; young jack rabbit, 3; young Leporidae, 2; meadow mouse, 2; young swamp sparrow, 1; young vesper sparrow, 1; dickcissel, 2; undetermined young warbler (Compsothlypidae), 1; young flicker, 1; young (less than week) pheasant, 1; young grebe, probably pied-billed *(Podilymbus podiceps)*, 1; frog, 2.

WEEK OF JULY 29 TO AUGUST 4: Three gullets. Contents: young cottontail, 1; striped ground squirrel, 2.

The weekly data are condensed for more convenient reference in Table 1, the prey types being listed in this case in the order of their numerical importance.

TABLE 3

Proportions of summer prey taken by Marsh Hawks at Madison, Wisconsin.

Prey Individuals	Number and Percent of Total			
	June to August, 1929	June and July, 1930	June and July, 1931	Three seasons 1929 to 1931
Young cottontails	None of 74 or 0.0 percent	12 of 115 or 10.43 percent	19 of 149 or 12.75 percent	31 of 338 or 9.17 percent
Mice, mostly meadow mice.	66 or 89.19 pct.	28 or 24.35 pct.	17 or 11.41 pct.	111 or 32.84 pct.
Sciuridae, mostly striped ground squirrels.	3 or 4.05 pct.	52 or 45.22 pct.	17 or 51.01 pct.	131 or 38.76 pct.
Shrews (*Blarina* sp. and *Sorex* sp.)	2 or 2.7 pct.		1 or 0.67 pct.	3 or 0.89 pct.
Fringillidae		3 or 2.61 pct.		3 or 0.89 pct.
Blackbirds		1 or 0.87 pct.	3 or 2.01 pct.	4 or 1.18 pct.
Meadowlarks and a few other Icteridae.	3 or 4.05 pct.	2 or 1.74 pct.	7 or 4.7 pct.	12 or 3.55 pct.
Miscellaneous passerine birds.		1 or 0.87 pct.	4 or 2.68 pct.	5 or 1.48 pct.
Flicker			1 or 0.67 pct.	1 or 0.29 pct.
Young domestic chicken.		1 or 0.87 pct.		1 or 0.29 pct.
Miscellaneous and undetermined birds, mostly probable passerines.		5 or 4.35 pct.	17 or 11.41 pct.	22 or 6.5 pct.
Frogs		10 or 8.7 pct.	4 or 2.68 pct.	14 or 4.14 pct.

Composite of Summer Food Habits

Table 2 summarizes the food habits of the hawks about Ruthven, Iowa, for the period studied, both according to specific summers and for the three seasons as a whole.

Of the 289 items of prey for the summer of 1933, 149 or 51.56 percent were mammals (mostly ground squirrels), 132 or 45.67 percent were birds (mostly Icteridae and other passerines), and 8 or 2.77 percent were amphibians (frogs). These represent prey for a season of "normal" precipitation.

For the drought season of 1934, the 158 listed prey items may be divided into 59 or 37.34 percent mammals (mostly ground squirrels), 95 or 60.13 percent birds (mostly Fringillidae, Icteridae and other passerines), 4 or 2.53 percent amphibians (frogs).

The 110 prey items for the wet season of 1935 were made up of 60 or 54.54 percent mammals (mostly young cottontails and ground squirrels), 46 or 41.82 percent birds (mostly Fringillidae, meadowlarks and other passerines), 4 or 3.64 percent amphibians (frogs).

Mammals comprise 268 or 48.12 percent of the 557 items recorded for the three summers; birds, 273 or 49.01 percent; amphibians, 16, or 2.87 percent.

For purposes of comparison, some Wisconsin summer data (Errington, '33a, pp. 20-21) have been summarized in Table 3.

Seventy-one or 95.95 percent of the 74 animals recorded for 1929 were

TABLE 4

Proportions of summer prey taken by Marsh Hawks in Anoka, Co., Minn.

Prey Individuals	Number and Percent of Total		
	June and July, 1932	June and July, 1933	Two seasons 1932-1933
Young cottontails.	5 of 66 or 7.58 percent	3 of 17 or 17.65 pct.	8 of 83 or 9.64 pct.
Mice, mostly meadow mice.	15 or 22.73 pct.	1 or 5.88 pct.	16 or 19.28 pct.
Pocket gopher	1 or 1.52 pct.		1 or 1.2 pct.
Sciuridae, mostly striped ground squirrels.	13 or 19.7 pct.	3 or 17.65 pct.	16 or 19.28 pct.
Small birds, mostly passerines.	19 or 28.79 pct.	3 or 17.65 pct.	22 or 26.51 pct.
Young ring-necked pheasant.	1 or 1.52 pct.		1 or 1.2 pct.
Bob-white	1 or 1.52 pct.	1 or 5.88 pct.	2 or 2.45 pct.
Frogs	1 or 1.52 pct.	2 or 11.76 pct.	3 or 3.61 pct.
Undetermined vertebrates, mostly mammals and birds.	10 or 15.15 pct.	4 or 23.53 pct.	14 or 16.87 pct.

mammals, very largely meadow mice which had reached an exceptionally high population peak; only 3 or 4.05 percent were birds (Icteridae). The following season (1930), 92 of 115 or 80 percent were mammals (mostly ground squirrels, with mice and young cottontails to a lesser extent); 13 or 11.3 percent, birds (mostly Fringillidae, Icteridae and other passerines); 10 or 8.69 percent, amphibians (frogs). The third season (1931), 113 of 149 or 75.84 percent were mammals (largely ground squirrels); 32 or 21.48 percent, birds (almost entirely passerines); 4 or 2.68 percent, amphibians (frogs).

For the three Wisconsin seasons, mammals represent 276 of 338 or 81.66 percent of the total items; birds, 48 or 14.2 percent; amphibians, 14 or 4.14 percent.

Breckenridge's Minnesota data on summer marsh hawk food habits are similarly summarized in Table 4 for comparison.

Food Habits of Marsh Hawks in Late Summer, Fall, Winter, and Spring

Our data on the food habits of the marsh hawk for seasons other than the nesting season are not too voluminous and we have had to use data from various sources to piece together any sort of coherent picture.

The food consumed by the young for some weeks after they begin flying is largely supplied them by the adults, as illustrated by the data earlier in this paper. The old birds gradually become less interested in the young, and the latter shift more and more for themselves. Awkward and inexperienced, the young may not find it easy to make a living, as one may deduce from their frequently observed hunting at all hours of the day in late summer and fall, the adults at this season satisfying their own needs without much effort.

Long before the family groups disperse and parental feeding ceases entirely, the young supplement the food supplied by adults with what slow, weak prey they themselves are able to catch, large insects in particular. Two lots totalling 38 mixed adult and juvenile pellets, collected in July and August, 1929, from near Madison, Wisconsin, contained varying quantities of insects in 20, spiders in 4, and a snail in 1. Some of these invertebrates (identified by the U. S. Biological Survey) were doubtless eaten as stomach contents of marsh hawk prey, but the insects were, for the most part, such Coleoptera as *Phyllophaga* sp. and other large forms which are regularly eaten when available by the juveniles of predaceous mammals and birds. Breckenridge found that a collection of 10 pellets disgorded by young birds recently on the wing contained just twice as many insects as did a similar collection of pellets of adults taken at the same time.

Garter snakes (*Thamnophis* sp.) seem to enter into the diet of marsh hawks somewhat more in late summer, and these are very likely to be among the first vertebrates to be caught by the clumsy juveniles. Of 310 June and July pellets gathered at Madison, Wisconsin, in 1930, 14 contained snake remains in conspicuous quantities.

We have little save field observations from which to draw conclusions with respect to the feeding of the self-sustaining juveniles. Their acceptance of the fresher grades of carrion which they may find in fields or along highways is evident from simple observation. Carcasses of poultry, ring-necked pheasants, and rabbits killed by motor traffic are highly available and are utilized by both young hawks and old. Juveniles—probably famished— occasionally try to attack prey which the adults leave alone; but after futile grabbing at flying small birds and perhaps some decisive rebuffs by species formidable enough to make the lessons smart, the young seem to adapt their hunting technique to their physical abilities and try for what they are more certain of getting. Grasshoppers *(Melanoplus* sp.) occur at times in extremely available numbers and are accordingly eaten by many predators, including marsh hawks.

Our recent (1930-'34) fall data are limited and represent those obtained from the contents of 10 stomachs and some general field observations. Cottontail remains judged to be carrion were found in 3 stomachs, and another stomach contained remains of a green-winged teal *(Nettion carolinense)* which was probably a bird lost or crippled by hunters. One other stomach contained the heart of a very large young bird, uncertainly determined as tame gosling, probably a traffic victim. Individuals of prey: meadow mouse, 6; Fringillidae, 3; red-winged blackbird, 1; cricket *(Gryllus* sp.), 3. Aside from a striped ground squirrel thought to represent killed prey, most of the items observed to be eaten by marsh hawks in the field were of roadside carrion, principally rabbit.

The marsh hawk winters only sparingly in the southern part of the region with which we are concerned, and, as a consequence, we do not have many quantitative data for this season either. These are mainly from 8 stomachs, 2 high-grade pellets, and 4 field observations. Items: carrion cottontail in two instances; meadow mouse, 18 individuals; deer mouse, 1; shrew *(Sorex* sp.), 1. In addition to the mice and frozen carrion which seem to constitute staple winter foods, marsh hawks may prey to some extent upon bob-whites, particularly those that are in weakened condition or are forced to live in unfavorable or over-crowded habitats.

Our chief source of information on early spring food habits has been the contents of 19 stomachs, mostly of those sent to Breckenridge by Minnesota cooperators in 1933. Three of these were empty, and, of the others, 6 contained cottontail and 1 jack rabbit, probably carrion in all cases. Small vertebrate prey included: meadow mouse, 4; deer mouse, 1; Franklin's ground squirrel (possibly carrion), 1; Fringillidae, 2; frog, 1. One stomach contained remains of a cock pheasant which was surely carrion; and another contained portions of a hen pheasant which evidently represented a kill. A mass of broken bits of feathers filled up one stomach and doubtless indicated scavenging, probably upon a large gallinaceous bird. One insect was found—an undetermined beetle.

Food habits data of quantitative status for late spring but prior to the

nesting season are available mainly from observational notes and from examination of the bony contents of Wisconsin pellets, 1930-'31. We may list the following individuals of prey: Very young cottontail, 1; young Norway rat *(Rattus norvegicus)*, 1; meadow mouse, 18; short-tailed shrew, 1; savannah sparrow, 1; garter snake, 1.

On the whole, the diet of the marsh hawk during the colder months appears to run strongly to small mammals such as mice, with a varying proportion of small birds from sparrow to blackbird sizes. Studies by Stoddard ('31, pp. 209-211) on marsh hawk wintering grounds in Georgia support this conclusion, as do the general food habits data presented by Fisher ('93) and McAtee ('35).

The Adaptations of the Marsh Hawk for Securing Prey

The marsh hawk is a raptor of rangy build and comparatively weak grasp. It rarely attacks mammals larger than third-grown cottontails, two-thirds grown Franklin's ground squirrels, and adult striped ground squirrels; nor birds larger than flickers, mourning doves, half-grown domestic chickens, three fourths grown ring-necked pheasants, and adult Hungarian partridges. The great preponderance of its prey is, indeed, of sizes much smaller than these, although astonishingly large tender-fleshed immatures may now and then be taken.

There is, of course, much difference in prey sizes that individual hawks are able to handle, since the females are decidedly larger and stronger. Prey animals of the usual small sizes—mice, very young ground squirrels, Fringillidae, etc.—are dispatched and eaten more or less easily, the heads often being pulled off and swallowed soon after capture. Prey animals of larger and intermediate sizes are held without difficulty, but the capturing hawk may not have the strength to sink its talons deeply enough into the body of its catch to kill it; in such cases, the hawk usually does a certain amount of plucking, biting, and eating of flesh from neck and breast until the victim finally dies.

In flight, the marsh hawk is much too slow to overtake many birds on the wing, with the execption of heavy-flying juveniles or individuals handicapped as by injuries or weaknesses. It can drop swiftly, however, and is agile in striking out in all directions with its long legs. Its characteristic low gliding over fields and marshes permits it to surprise alert and quick-moving animals which it could not otherwise expect to capture. It is at a disadvantage flying through trees and is seldom seen doing so; it may, nevertheless, quarter over low woodlands, as well as it does over weedy or brushy grounds, ready to wheel and dive into openings after some mammal or fledgling that may be tardy about getting into suitable cover.

Temperamentally, marsh hawks are quite variable, but it seems safe to state that the species shows considerable adaptability, though here again we may not be sure how much behavior may be due to inheritance and how much to experience. That at least some marsh hawks are well able to learn from

experience and to modify their living routine accordingly is a conclusion to be drawn from observations both of captive and of free birds.

So far as we can see, the marsh hawk is but slightly selective in its preying and exhibits very few if any food preferences. Captive young have displayed a distaste for frogs when first fed, soon accepting them, however, as regular articles of diet. Entrails of young rabbits, ground squirrels, or of other young animals containing a large proportion of vegetable debris or foul-smelling material, are commonly discarded, and we have not observed the birds feeding on carrion after putrefaction has advanced. But, with respect to prey types on the whole, the hawks do not seem to care especially what they take, as long as the prey may be conveniently caught and handled.

Immatures* of various prey species bear the brunt of marsh hawk pressure during the summer, for the primary reason that they are easy to find and are not so adept at escaping. Adults may fall prey as they may be caught through surprise or chance or through disadvantageous environmental changes. Mowing of alfalfa and haylands, harvesting of small grains, close grazing by livestock of pastures and road-sides, burning, plowing, floods, autumnal changes in vegetation or those accompanying drought, and other human activities of natural phenomena bringing about wide scale modifications of environment, all may result in exposure of prey populations in some habitats and over-crowding in others, with a consequently increased vulnerability to the depredations of marsh hawks and similar raptorial enemies.

Marsh hawks seemingly range over a relatively limited portion of their hunting grounds at a time, but work that portion thoroughly, going again and again over the same route. Then, when the easily available victims have been picked off and the general prey population has become too wary or too secure otherwise to make continued hunting profitable, the hawks modify their hunting routine to cover territory that has not suffered such recent exploitation. This tends to result in "waves" of certain prey species appearing in the diet of certain hawk families.

For example, flickers were represented at one nest on 9 of 14 consecutive gullet collections, whereas only 4 were found during the rest of the season for 86 gullet collections. All three of the young screech owls listed as prey were brought to one nest, 2 owlets in one day and the third seven days later. Young domestic chickens of different sizes may be brought in every day for a few days, then few if any for the duration of the season. The same may be said of rails, young pheasants, frogs, and other species which are not usually staple marsh hawk foods, but which occur in its diet with varying frequency.

These "waves" of prey items are noticeably conspicuous from week to week when the hawks are living upon what we may call staple foods. For a few days, there will be a "wave" of ground squirrels, then of young rabbits,

* The proportion of immatures taken is in actuality considerably higher than that shown in the tabulations, for the distinction between adults and full-sized juveniles was not always made in the notes, even when evident at the time of examination.

mice, blackbirds, perhaps ground squirrels again, sparrows, meadowlarks, with miscellaneous items sprinkled promiscuously throughout the list. We doubt if the shifting of pressure from one prey species to another reflects selectivity on the part of the hunting hawks; in all probability what is taken is governed on the whole by what is most available or most vulnerable to attack in the sundry environmental types over which the marsh hawks hunt. Breckenridge, in his studies from a blind, has noted several young of identical size of both cottontails and striped ground squirrels to be brought to a nest at very short intervals, and he suspected these of being members of particularly accessible family groups.

Marsh Hawk Pressure Upon Prey Populations

McAtee's ('32) generalization to the effect that predation tends to be in proportion to population was founded chiefly on a study of the food habits of insectivorous birds and seems to govern the feeding of marsh hawks on insects and lower vertebrates about as much as anything we can see, size limits and availability in habitats also being considered. For prey species of manageable sizes, sluggish in movement, and possessed of the more stereotyped behavior patterns, it seems broadly true that the more abundant they are the more heavily they will be preyed upon. Young of more active and more highly organized species may fall into this category during the period of their greater helplessness.

There is evidence, however, that a great deal of predation may not be so much in proportion to population as to *over-population* (Errington, '35c; Errington and Hamerstrom, '36). In other words, recent and current researches seem to indicate that a number of vertebrate prey populations may be composed of distinctly vulnerable over-populations and comparatively secure residua, the proportions of these two varying with the species and with its population levels in relation to the accommodation capacity of its habitat, and having little evident connection with the kinds and numbers of predators ordinarily present.

While the bob-white is the only wild vertebrate species which has been studied with sufficient thoroughness to justify conclusions as to the mechanism of predation and the net effect thereof upon population levels (Stoddard, '31; Errington, '34; Errington and Hamerstrom, '36), the accumulating data from other researches show a trend of thought away from the idea that predation has a dominant influence on animal numbers collectively. There are doubtless many prey species the abundance of which may be strongly influenced at one time or another by the pressure of natural enemies; but the more local intensive studies are carried on the less apparent it seems that predation is as much of a limiting population factor as we have been in the habit of assuming. An increasing awareness of the role of weather, food, cover, intra-specific territorial relationships, non-predaceous competition, breeding rhythms, the imperfectly understood phenomena associated with "cycles," etc., makes it appear more and more that predation is but a symptom rather than a cause of much population instability.

Indeed, so much of the predation upon some species—bob-white, for instance (Errington, '34; Errington and Hamerstrom, '36)—seems to be confined to portions of populations which are, in analysis, unproductive or insecure to the extent of being doomed anyway, that one may be tempted to postulate more with respect to other species than our present grounds may justify. For all of that, we may touch briefly upon the trend of the findings of other population researches.

Gause ('34, p. 24) quotes Kalabuchov and Raewski to describe the secure position of mouse populations in the Caucasus after the removal through predation of what evidently amounts to the vulnerable surplus. Errington has similar but fragmentary data which hint that cottontail and muskrat *(Ondatra zibethica)* populations may also show thresholds of comparative security, even at times when the populations may by no means be reduced to insignificant levels.

Nice ('36) finds for the song sparrow *(Melospiza melodia beata)* a correlation between severity of losses from enemies and the adequacy of its environment. This being the case, we may expect the principle to hold for a host of small passerine birds of like habits and living requirements.

Our local studies of nesting waterfowl (Errington and Bennett, '34; Bennett, '35) have brought out very plainly a connection between the quality of the environment and the losses from predation suffered, especially by eggs and young.

Considerable work has been done on the ring-necked pheasant (Hamerstrom, '36; Spawn, unpublished) to determine how much its population levels may be influenced by predation and how much by factors such as food, cover, territory, etc., but we have insufficient basis for many conclusions. We are coming to suspect that predation may be of greater importance in the life equation of this species than seems true for the bob-white. The Hungarian partridge, another introduced species, has been studied in this country, notably by Yeatter ('34), but it is still something of an enigma in many respects.

It is our growing impression from the severity of predation upon exotic species which has been recorded (Breckenridge, '35c; Errington, '35a; '35b; and unpublished), that some of these may not be too well adjusted to their racially new environments. This is advanced purely as a possibility, and not as a substantiated fact.

It is true that the marsh hawk may not exert such a blanket pressure upon vulnerable prey species as general predation may, but it is often to be seen that prey species are vulnerable both to specific and to general predation. If a species is decidedly vulnerable to the marsh hawk, the chances are that it is vulnerable to other predators also; if vulnerable to general predation it will probably yield toll to the marsh hawk among other predators, although not necessarily in the same way or at the same times.

By and large, the weight of predation seems to be borne by that proportion of the prey populations which may be living at the greatest disadvantage.

This boils down essentially to a matter of there being more prey animals present than their habitats can take care of, whether through increase of populations or through decrease—temporary or otherwise—of environmental carrying capacity. And, broadly speaking, there are usually enough prey animals of some sort insecurely situated from one cause or another to keep ordinarily heavy predator populations well fed; and the net weight of the resulting pressure usually does not approach that which the prey species could safely bear if they had to. Predators as well as non-predators have their own natural population checks, and, as McAtee ('36) has written, only under exceptional circumstances do wild populations increase up to or even near the limit of their available food supply.

Summary

Summer food habits studies in Iowa, Minnesota, and Wisconsin have given us recent data on nearly a thousand individuals of vertebrate prey taken by marsh hawks hunting in areas we have under some degree of contemporaneous ecological observation. Supplementing the summer data, we have some for other seasons, although these have been acquired from miscellaneous sources and from localities with which we were familiar in but a superficial way.

The marsh hawk, in common with most other predators, seems to feed chiefly upon whatever it finds conveniently available as food, whether that food be carrion (of fresher grades) or captured prey. The carrion eaten is represented in large measure by carcasses of animals killed along highways by motor traffic; the prey, by young rabbits, mice, the smaller ground squirrels, passerine birds, and young or crippled individuals of larger species, including ring-necked pheasants.

From the findings of intensive studies of vertebrate populations, it is becoming increasingly apparent that the rôle of predation in determining population levels of prey species may be of far less consequence on the whole than has been previously believed. A great deal of the pressure of predators—that of marsh hawks included—seems to be centered upon those proportions of the prey populations that tend to exceed the capacities for accommodation of their respective habitats.

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The Genus Carex in Kansas *

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It is generally known that the genus *Carex* is the largest of the genera of flowering plants comprising the flora of northeastern and central United States. In most of these states it is represented by well over a hundred species. Thus House[1] reports 188 species for the state of New York and Benner[2] lists 113 authenticated species from a single county in eastern Pennsylvania. Again in the Rocky Mountains and in the Pacific states it is among the largest genera and the plants are often sufficienty abundant to form a conspicuous element in the vegetation. In the intervening area of the Great Plains, however, where the diversity of habitats is so much smaller than it is east or west of them, there is naturally a marked decrease in the number of species of such a genus which requires a variety of habitats for its greatest development. Hence we find in Kansas none of the *Carices* which flourish in the bogs of the northeastern states and most of the large groups inhabiting rich, moist woods, or lake shores, or marshes, are lacking. The woodlands of the easternmost counties, however, have contributed a large number of species otherwise unrepresented in the state, particularly the alluvial woods and low thickets along the Missouri River in Wyandotte and Leavenworth Counties, and this group brings the number of species known from Kansas to a total rather larger than one might expect.

A recent study of the *Junci* in Kansas[3] disclosed the occurrence of several species not previously known from the state and suggested the desirability of a similar study of the *Carices*. All of the *Carex* material in the Kansas State Herbarium, as well as the more significant collections selected by Dr. F. C. Gates from the herbaria of the University of Kansas and the Sacred Heart Academy, has been reviewed, therefore, by the writer and the results are presented in this paper.

A few general observations may be made regarding the genus as now known in Kansas. Of the forty-eight species and two well-marked geographic varieties represented in the herbaria of the state, two *(C. Eleocharis* and *C. nebraskensis)* have entered the state from the west and are apparently

* Paper from the Department of Botany and the Herbarium of the University of Michigan, no. 575.

1 H. D. House, N. Y. State Mus. Bull. no. 254. 1924.

2 W. M. Benner, The Flora of Bucks County, Pa. Philadelphia. 1932.

3 F. J. Hermann, The Distribution of Juncus in Kansas. Papers Mich. Acad. Sci. 20:37-47. 1934.

confined to the western counties; eleven are generally distributed throughout the state, two of these *(C. praegacilis* and *C. lanuginosa)* being derived from the west and nine from the east; and the remaining thirty-seven are eastern plants rarely, if at all, found in the western half of Kansas. Eight of these eastern *Carices* are confined, so far as the records show, to Wyandotte and Leavenworth Counties where they probably occur only on the alluvial soils along the Missouri River. Three others are represented only from Cherokee County, which occupies the southeastern corner of the state. The collections of these species are without exact locality data so that it is not apparent whether their presence in Cherokee County is related to physiographic or geologic features, but the extension from the east of the Ozark Pleateaus into this county (here underlaid by the Boone limestone formation) is suggestive that they may be associated with them.

It is not surprising that with few exceptions the species of *Carex* found in Kansas are those showing pronounced affinity for calcareous soils.

In the following list those species prefixed with an asterisk are apparently new to Kansas. They represent westward range extensions of eastern species, with the exception of *C. microdonta*, a southern species for which the known range is extended northward. This species is also new to the area included by Gray's *New Manual of Botany*, Britton and Brown's *Illustrated Flora* and Rydberg's *Flora of the Prairies and Plains*.

Specimens cited are in the Kansas State Herbarium at Manhattan except where followed by the abbreviation "U," indicating the Herbarium of the University of Kansas at Lawrence; "S," indicating the Herbarium of the Sacred Heart Academy at Wichita; or "T," indicating the Herbarium of the Kansas State Teachers' College at Emporia. The writer is indebted to Dr. F. C. Gates of the Kansas State College for the privilege of examining this material, and to Dr. H. A. Gleason of the New York Botanical Garden for the loan of specimens of *C. austrina* from Kansas. This species was not found to be represented in the Kansas herbaria but, as mentioned, authentic material of it from Kansas is found in the Herbarium of the New York Botanical Garden.

A key to the species of *Carex* known to occur in Kansas is included here in the hope that it may be of use to students of the local flora. It is based in part upon that of Rydberg in his *Flora of the Prairie and Plains of Central North America* and that of Mackenzie in Vol. 18 of *North American Flora*. Mackenzie's monograph, too, is followed in the phylogenetic sequence of sections and species.

Key to Carex in Kansas.

Stigmas 2 and achenes lenticular; spikes usually bisexual, the lateral sessile. ----------Sub-genus *Vignea*.

Stigmas 3 and achenes triangular, or if stigmas 2 and achenes lenticular, the lateral spikes peduncled; spikes nomally unisexual. ----------Sub-genus *Eu-Carex*.

Sub-genus *Vignea*.

Rootstocks long-creeping, the culms solitary or arising few together. ——I. *Divisae*.

Rootstocks not long-creeping, the culms cespitose.
Spikes androgynous (i.e. staminate flowers above pistillate).
Perigynia (2-4.5 mm. long) abruptly contracted into the beak.
Spikes few (10 or less); sheaths not both tight and transversely rugulose ventrally. ——II. *Bracteosae*.

Spikes very numerous; sheaths tight and transversely rugulose ventrally. ——*III. Multiflorae*.

Perigynia (4-7 mm. long) tapering into the beak. ——IV. *Vulpinae*.

Spikes gynaecandrous (i.e. pistillate flowers above staminate).
Perigynia thin-edged, not wing-margined, the lower part of the body spongy-thickened. ——V. *Stellulatae*.

Perigynia narrowly to broadly wing-margined, the lower part of the body not spongy-thickened. ——VI. *Ovales*.

Sub-genus *Eu-Carex*.

Scales bract-like; achenes strongly constricted at base, rounded at apex. ——VII. *Phyllostachyae*.

Scales not bract-like; achenes not strongly constricted at base, pointed at apex.
Achene closely enveloped by the perigynium; bracts sheathless or nearly so.
Perigynia obtusely triangular; plant (except perigynia) glabrous. ——VIII. *Montanae*.

Perigynia sharply triangular; plant pubescent. ——IX. *Triquetrae*.

Achene not closely enveloped by the perigynium, or if so, bracts strongly sheathing.
Lowest bract strongly sheathing; perigynia not strongly bidentate with stiff teeth.
Pistillate spikes short-oblong to linear, erect.
Perigynia with few to many strong, raised nerves.
Perigynia tapering at base, triangular; achenes usually closely enveloped.
Rootstock long-creeping. ——X. *Paniceae*.

Rootstock not long-creeping. ——XI. *Laxiflorae*.

Perigynia rounded at base, suborbicular in cross-section; achenes loosely enveloped. ——XII. *Granulares*.

Perigynia with numerous fine, impressed nerves.
Perigynia tapering at base, constricted at the apex, obtusely triangular; achene closely enveloped. ——VIII. *Oligocarpae*.

Perigynia rounded at both ends, terete. —— XIV. *Griseae*.

Pistillate spikes linear-oblong, slender-peduncled, the lower drooping. ——XV. *Gracillimae*.

Lowest bract sheathless, or if sheathing, the perigynia strongly bidentate with stiff teeth.

Foliage pubescent; perigynia not bidentate. ----------XVI. *Virescentes.*

Foliage glabrous, or if rarely pubescent, perigynia bidentate.
Perigynia pubescent coriaceous ----------XVII. *Hirtae.*

Perigynia glabrous.
Perigynia transversely corrugated, very short-beaked, achenes triangular.
---------- XVIII. *Shortianae.*

Perigynia not transversely corrugated; with strongly bidentate beak, or if not, achenes lenticular.
Achenes lenticular; perigynia dull. ----------XIX. *Acutae.*

Achenes triangular.
Perigynia finely and closely ribbed. --------XX. *Pseudo-Cyperae.*

Perigynia either coarsely ribbed or with impressed nerves.
Perigynia subcoriaceous and firm. ----------XXI. *Paludosae.*

Perigynia thin and membranaceous.
Perigynium-body obovoid or obconic, truncately contracted into the beak. ----------XXII. *Squarrosae.*

Perigynium-body ovoid, not truncately contracted.
----------XXIII. *Lupulinae.*

Section I. DIVISAE.

Rootstocks slender, light brown; culms usually smooth; leaves strongly involute; perigynia 2.5-3 mm. long, the beak less than half the length of the body.
----------1. *C. Eleocharis.*

Rootstocks stout, blackish; culms normally rough above; leaves flat or channeled; perigynia 3-4 mm. long, the beak half the length of the body or more.
----------2. *C. praegracilis.*

1. CAREX ELEOCHARIS L. H. Bailey, Mem. Torr. Bot. Club 1:6. 1889.
"*C. stenophylla* Wahl." of recent manuals.

Dry plains and prairies. Chiefly in northern counties of western third of state.

Cheyenne Co., *A. S. Hitchcock*, June 28, 1897. Logan Co., Winona, *A. S. Hitchcock*, May 1850. Riley Co., Manhattan, *J. B. Norton*, May 1894 and April 1895. Sheridan Co., *C. Weber* 270. Thomas Co., *A. S. Hitchcock* 1024 (in part).

2. CAREX PRAEGRACILIS W. Boott, Bot. Gaz. 9:87. 1884

C. marcida Boott, 1839; not J. F. Gmel., 1791.

C. camporum Mackenzie, 1910.

Moist plains and prairies. Throughout, but rare in eastern half of state. A highly polymorphic species.

Anderson Co., *A. S. Hitchcock*, July 1896. Cheyenne Co., *A. S. Hitchcock*, June 28, 1897. Cloud Co., Concordia, *A. S. Hitchcock*, June 17, 1897; *S. V. Fraser* 33. Decatur Co., *A. S. Hitchcock*, June 2, 1897. Finney Co., grassland, *Wilson & Miller*, July 18, 1912 (U). Ford Co., Dodge City, *A. S. Hitchcock*, July 1892. Graham Co., *A. S. Hitchcock*, June 20, 1897. Hamilton Co., Coolidge, *A. S. Hitchcock*, July 4, 1892. Kearney Co., *Wilson & Miller*, July 11, 1912 (U). Logan Co., Winona, *A. S. Hitchcock*, May 1895. Rooks Co., Rockport, *E. Bartholomew*, without date. Sheridan Co., *C. Weber* 262. Sherman Co., Goodland, *F. Agrelius*, Feb. 28, 1911 (T). Thomas Co., *A. S. Hitchcock* 1024 (in part). Wabaunsee Co., prairie west of Wabaunsee, *P. Maus*, April 29, 1927.

Section II. BRACTEOSAE.

Sheaths tight, inconspicuously if at all mottled with green and white or septate-nodulose dorsally; leaf-blades narrow (1-5 mm. wide).

Perigynia corky-thickened at base, usually widely spreading or reflexed at maturity.

Beak of perigynium smooth; scales acuminate, deciduous. ___3. *C. retroflexa.*

Beak of perigynium minutely serrulate; scales obtuse or acutish, persistent.

Stigmas long and slender, usually not twisted, light reddish; perigynium tapering into the beak; leaves 2 mm. or less wide. 4. *C. rosea.*

Stigmas stout and strongly twisted or contorted, deep red; perigynium rather abruptly contracted into the beak; leaves averaging 2.5 mm. wide. _____5. *C. convoluta.*

Perigynia not corky-thickened at base, mostly ascending.

Scales (excluding awns) much shorter than the perigynium-bodies; perigynia smooth or obscurely few-nerved dorsally, inflorescence oblong-ovoid to suborbicular, capitate.

Perigynia with margins raised ventrally, round-tapering at base, broadest below the middle, gradually contracted into the serrulate beak. _____6. *C. cephalophora.*

Perigynia flat ventrally, broadest at the truncate-cordate base, usually abruptly contracted into the short, smooth beak. 7. *C. Leavenworthii.*

Scales (excluding awns) from little shorter than to much exceeding the perigynium bodies; perigynia strongly ribbed dorsally; inflorescence oblong to elongate and interrupted, rarely capitate.

Perigynia spreading, 3-3.5 mm. long; bracts not broadly dilated at base; scales about the length of and narrower than the bodies of the perigynia, cuspidate or short-aristate. 8. *C. Muhlenbergii* var. *enervis.*

Perigynia ascending, 3.5-5 mm. long; bracts broadly dilated at base; at least the lower scales exceeding and as wide as the perigynia, long-awned. _____9. *C. austrina.*

Sheaths loose, mottled with green and white and usually septate-nodulose dorsally.

Perigynia not deep-green, the beak one-third to one-fourth the length of the ovate or suborbicular body, or if longer, the ventral suture deep.

Perigynia ovate, tapering into the beak, typically smooth or faintly nerved dorsally; beak very sharply bidentate, the teeth about 1 mm. long; pistillate scales mostly strongly awned; leaf-blades rarely over 5 mm. wide. _____10. *C. gravida.*

Perigynia broadly ovate to suborbicular, abruptly beaked, typically strongly ribbed dorsally; beak less sharply bidentate, the teeth about 0.5 mm. long; pistillate scales mostly acuminate to short-awned; leaf blades often 6-8 mm. wide. _____10a. *C. gravida* var. *Lunelliana.*

Perigynia deep-green, the beak one-third the length of the ovate body or more, or if rarely shorter, the ventral suture shallow.

Perigynia flat ventrally; stigmas long and slender; leaf-blades 3-6 mm. wide; sheaths usually not transversely rugulose; spikes usually approximate; culm sulcate (the ridges white) up to the inflorescence, smooth or rarely minutely serrulate on the angles._____ 11. *C. aggregata.*

Perigynia with raised border ventrally; stigmas short and stout; leaf-blades 5-10 mm. wide; sheaths usually transversely rugulose; lower

spikes usually separate; culm sulcate only below, narrowly winged or margined, the angles serrulate. ---------- 12. *C. sparganioides.*

*3. CAREX RETROFLEXA Muhl.; Willd. Sp. Pl. 5:237. 1805.

Dry woods and thickets. Eastern.

Cherokee Co., *A. S. Hitchcock*, May 1896.

*4. CAREX ROSEA Schkuhr; Willd. Sp. Pl. 4:237. 1805.

Dry woods. Eastern border of state.

Franklin Co., *B. B. Smyth*, June 1901. Wyandotte Co., Quindaro, *K. K. Mackenzie*, May 30, 1897.

6. CAREX CONVOLUTA Mackenzie, Bull. Torr. Bot. Club 43:428. 1916.

Dry woods. Eastern border of state.

Leavenworth Co., *A. S. Hitchcock* 867. Wyandotte Co., *A. S. Hitchcock*, May 3, 1897; Quindaro, *K. K. Mackenzie*, May 30, 1897.

6. CAREX CEPHALOPHORA Muhl.; Willd. Sp. Pl. 4:220. 1805.

Dry woods. Eastern third of state.

Cherokee Co., 8 miles south of Galena, *Rydberg & Imler* 274 (in part) (U). Riley Co., Stag Hill, *F. C. Gates* 12686. Wyandotte Co., Argentine, *M. Reed*, June 4, 1890.

7. CAREX LEAVENWORTHII Dewey, Am. Jour. Sci. II. 2:246. 1846.

Dry, open woodlands. Eastern half of state.

Chautauqua Co., *A. S. Hitchcock*, May 7, 1897. Cherokee Co., *A. S. Hitchcock*, May 1896; May 7, 1897. Cloud Co., *S. V. Fraser* 20. Crawford Co., *Rydberg & Imler* 171 (U).

8. CAREX MUHLENBERGII Schkuhr, var. ENERVIS Boott, Ill. Carex 124. 1862.

C. plana Mackenzie.

Dry hillsides. Eastern.

Cherokee Co., *Rydberg & Imler* 274 (in part), June 25, 1925.

9. CAREX AUSTRINA (Small) Mackenzie, Bull. Torr. Bot. Club 34:151. 1907.

C. Muhlenbergii var. *austrina* Small.

Dry, open places. Local; a southern species.

Cloud Co., *M. A. Carleton*, May 19, 1888 (N. Y. Bot. Gard.). Ford Co., Bucklin, *A. S. Hitchcock*, July 1892 (N. Y. Bot. Gard.).

10. CAREX GRAVIDA L. H. Bailey, Mem. Torr. Bot. Club 1:5. 1889.

C. gravida var. *laxifolia* L. H. Bailey.

Prairies and plains. Throughout.

Cloud Co., *M. A. Carleton*, May 15, 1888. Ford Co., Bucklin, *A. S. Hitchcock*, Sept. 1892. Geary Co., *A. S. Hitchcock*, June 1896; *R. H. Imler*, May 28, 1929 (U). Hodgeman Co., *A. S. Hitchcock*, Aug. 1895. Leavenworth Co., *A. S. Hitchcock*, May 1896. Lincoln Co., *A. S. Hitchcock*, July 1895. Lyon Co., *F. Agrelius*, June 4, 1930 (T). Osake Co., *Z. D. E. Brown*, June 5, 1899. Osborne Co., *C. Weber* 118 (in part). Ottawa Co., *A. S. Hitchcock*, July 1895. Pottawatamie Co., *W. Wahl* 74. Reno Co., *F. C. Gates* 17107. Riley Co., *R. H. Imler*, May 27, 1929 (U); Manhattan, *J. E. Payne*, May 23, 1894; Manhattan, *R. F. Copple* 73. Saline Co., *J. B. S. Norton*, Sept. 1895. Sedgwick Co., *M. Aquinas*, April 26, May 6, May 9, May 23, 1933 (S). Shawnee Co., *B. B. Smyth*, May 1891. Sheridan Co., *C. Weber* 262.

Shermana Co., Goodland, *A. S. Hitchcock*, June 26, 1892. Thomas Co., *A. S. Hitchcock*, June 23, 1897. Washington Co., northwest of Linn, *J. C. Dodd, Jr.*, in 1932.

The following collections approach var. *Lunelliana*.

Cloud Co., Concordia, *A. S. Hitchcock*, June 17, 1897; *S. V. Fraser* 34. Dickinson Co., *A. S. Hitchcock*, June 1896. Harvey Co., *F. C. Gates* 15187. Rawlins Co., *A. S. Hitchcock*, June 1897. Riley Co., *F. C. Gates* 14767. Rooks Co., Rockport, E. Bartholomew, June 8, 1890. Saline Co., *J. Hancin* 936. Shawnee Co., Topeka, *B. B. Smyth*, May 1895.

10a. CAREX GRAVIDA L. H. Bailey, var. LUNELLIANA (Mackenzie) comb. nov.

C. Lunelliana Mackenzie, Bull. Torr. Bot. Club 42:615. 1915.

Prairies. Chiefly in the eastern half of the state.

Cherokee Co., *A. S. Hitchcock*, May 1896; *A. A. Jacobs* 88. Clay Co., *S. J. Norton* in 1891; Wakefield, June 8, 1892; Clay Center, *C. Weber* 24. Cloud Co., *S. V. Fraser* 19. Douglas Co., *F. H. Snow* 3224 (U). Geary Co., *A. S. Hitchcock*, June 1896. Harvey Co., Emma Creek, *F. Agrelius*, July 10, 1903 (T). Linn Co., Pleasanton, *Rydbereg & Imler* 84 (U) and 117 (U). Montgomery Co., *A. S. Hitchcock*, May 9, 1897. Nemaha Co., *Clothier & Whitford*, July 27, 1897. Pratt Co., *F. C. Gates* 15164. Republic Co., without collector or date. Riley Co., Manhattan, *S. M. Munger*, May 1882; prairie, *J. B. Norton* 557; Manhattan, *R. F. Copple* in 1920; Manhattan, *C. O. Johnston* 72; Manhattan, *F. C. Gates* 14089 and VDJTV; Wild Cat, *M. Mather*. Saline Co., near Gypsum, *F. C. Gates* 15126. Sedgwick Co., *M. A. Carleton*, May 17, 1889; *H. C. Misioner*, May 1889. Shawnee Co., Topeka, *B. B. Smyth* 823, 843 and May 29, 1891. Washington Co., northwest of Linn, *T. C. Dodd, Jr.* in 1933.

The following collections approach var. *typica*.

Rice Co., east of Lyons, *F. C. Gates* 15137. Sheridan Co., *A. S. Hitchcock*, June 21, 1897; *C. Weber* 261.

Toward the eastern limit of its range this plant is generally amply distinct from *C. gravida* but in Illinois intermediates are found and in Kansas transitional forms become abundant. Here plants possessing most of the characteristics of *C. gravida* but with the short-toothed, abruptly-beaked pergynia of *C. Lunelliana* are common; others are predominantly *gravida* except for dorsally ribbed perigynia, etc. *C. Lunelliana*, then, cannot be logically maintained as a species, but its manifest distinctiveness in the eastern part of its range and its marked geographic segregation manifestly entitle it to varietal recognition. I have been unable to correlate the relative length of the ligule, as employed by Mackenzie, with the other diagnostic characters which commonly differentiate the two plants.

11. CAREX AGGREGATA Mackenzie, Bull. Torr. Bot. Club 37:264. 1910.

C. agglomerata Mackenzie 1906; not C. B. Clarke, 1903.

Borders of woods or thickets, and rich, grassy slopes. Northeastern counties.

Brown Co., Fairview, *B. Skinner*, June 1888; *F. Garner*, August 1925. Riley Co., Wild Cat, *J. E. Payne*, May 12, 1894. Saline Co., woods northwest of Salina, *J. Hancin* 922. Shawnee Co., Topeka, *B. B. Smyth*, June 1898. Wabaunsee Co., Vera, *J. B. S. & G. L. C. Norton*, without date.

12. CAREX SPARGANIOIDES Muhl.; Willd. Sp. Pl. 4:237. 1805.

Borders of woods and thickets. Eastern.

Leavenworth Co., *A. S. Hitchcock*, May 1896. Wyandotte Co., rich woods, Quindaro, *K. K. Mackenzie*, May 30, 1897.

Section III. MULTIFLORAE.

Beak of perigynium much shorter than the body; leaves usually shorter than the culms. ----------13. *C. annectens* var. *xanthocarpa*.

Beak of perigynium about equaling the body; leaves normally exceeding the culms. ----------14. *C. vulpinoidea*.

13. CAREX ANNECTENS Bickn., var. XANTHOCARPA (Bickn.) Wiegand, Rhodora 24:74. 1922.

C. xanthocarpa Bickn. 1896; not Degland, 1807.

C. brachyglossa Mackenzie, 1923.

Fields and pastures. Eastern.

Cherokee Co., *A. S. Hichcock*, May 1896. Lyon Co., *F. Argelius*, July 3, 1930 (T).

14. CAREX VULPINOIDEA MICHX. Fl. Bor. Am. 2:169. 1803.

Low fields and swamps. Throughout.

Barber Co., Medicine Lodge, *A. S. Hitchcock*, July 1892. Barton Co., 3 miles southeast of Hoisington, *Rydgerg & Imler* 1270 (U). Butler Co., White Water, *A. S. Hichcock*, August 1892. Clay Co., Clay Center, *C. Weber* 90. Cloud Co., *S. V. Fraser* 21. Douglas Co., *Z. D. E. Brown*, May 23, 1899. Ellis Co., *J. A. Rich* 118; Hays, *E. Bartholomew* 953. Ellsworth Co., *A. S. Hitchcock*, July 1895; Wilson, C. *Weber* 10. Greenwood Co., Eureka, without collector or date. Harvey Co., Newton, *F. Agrelius*, August 8, 1907 and July 13, 1909 (T). Johnson Co., *Clothier & Whitford*, August 7, 1897. Lyon Co., *F. Agrelius*, June 4, 1930. McPherson Co., McPherson, *A. S. Hitchcock*, July 1892. Miami Co., Paula, *M. Reed*, August 1892. Osborne Co., *C. Weber* 177. Ottawa Co., *A. S. Hitchcock*, July 1895. Pottawatamie Co., *W. Wahl* 33; Onaga, *F. F. Crevecoeur* in 1895. Riley Co., Manhattan, *M. A. Carleton*, June 20, 1892; *J. B. Norton* 561. Rooks Co., *E. Bartholomew*, June 1889. Saline Co., Salina, *J. Hancin* 941. Seward Co., Arkalon, *A. S. Hitchcock*, July and August 1892. Shawnee Co., Topeka, *B. B. Smyth*, July 1886, May 1892, and May 1905; moist ravine north of Auburn, *P. Maus* 844. Sheridan Co., *C. Weber* 43. Trego Co., *A. S. Hitchcock*, July 1895. Wabaunsee Co., *J. B. S. Norton*, July 4, 1894; low pasture east of Wabaunsee, *P. Maus* 257. Washington Co., northwest of Linn, *T. C. Dodd, Jr.* in 1932. Wyandotte Co., common on low ground near Argentine, *K. K. Mackenzie*, June 7, 1896.

Section IV. VULPINAE.

Beak of perigynium equaling or longer than the body.

Perigynia 4-6 mm. long, strongly nerved ventrally, the beak 1-2 times the length of the body. ----------15. *C. stipata*.

Perigynia 6-7 mm. long, obscurely nerved ventrally except at base, the beak 2-3 times the length of the body. ----------16. *C. Crus-corvi*.

Beak of perigynium about half the length of the body, the body nerveless ventrally. ----------17. *C. conjuncta*.

15. CAREX STIPATA Muhl.; Willd. Sp. Pl. 4:233. 1805.

Wet meadows and swamps. Eastern half of state.

Cloud Co., *S. V. Fraser* 22. Crawford Co., *Rydberg & Imler* 175 (U). Riley Co., Manhattan, *W. A. Kellerman* 153. Saline Co., wet pasture 4 miles east of Assaria,

J. Hancin 912. Wyandotte Co., low ground, Quindaro, *K. K. Mackenzie*, May 30, 1897.

16. CAREX CRUS-CORVI Shuttlw.; Kunze, Suppl. Riedgr. 128. 1842.
Swamps. Eastern.

Wabaunsee Co., Maplehill, *J. B. S. Norton*, July 4, 1894. Wyandotte Co., swamp near Argentine, *K. K. Mackenzie*, June 7, 1896.

17. CAREX CONJUNCTA Boott, Ill. Carex 122. 1862.
Alluvial thickets. Eastern.

Douglas C., Lawrence, *F. Agrelius*, May 1 and June 11, 1910 (T). Wyandotte Co., low grounds near Argentine, *K. K. Mackenzie*, June 7, 1896.

Section V. STELLULATAE.

18. CAREX INTERIOR L. H. Bailey, Bull. Torr. Bot. Club 20:426. 1893.
C. scirpoides Schkuhr, in part.

Swampy meadows. Probably throughout.
Riley Co., *W. A. Kellerman*, May 8, 1888. Trego Co., *A. S. Hitchcock*, July 19, 1895.

Section VI. OVALES.

Perigynia lanceolate to narrowly ovate-lanceolate, 3-4 times as long as wide.
Leaves 1.5-3 mm. wide, those of the sterile shoots few, ascending. 19. *C. scoparia.*

Leaves broader, those of the sterile shoots numerous, widely spreading.
Perigynia 3-6.5 mm. long; achenes oblong-oval, 1.5 mm. long; spikes 4-15 mm. long. ---------- 24. *C. tribuloides.*

Perigynia 7-10 mm. long; achenes linear-oblong, 2.5 mm. long; spikes 15-25 mm. long. ---------- 25. *C. muskingumensis.*

Perigynia ovate-lanceolate or broader, at most twice as long as wide.
Perigynia 3-4 mm. long, 1.5-2 mm. wide, narrowly to broadly ovate. ---------- 20. *C. normalis.*

Perigynia 4-6.5 mm. long, 2.25-4 mm. wide, broadly ovate to suborbicular.
Perigynia plano-convex, coriaceous or submembranaceous, 4-5.5 mm. long.
Perigynia often suborbicular, abruptly contracted into the beak, coriaceous, nerveless or nearly so ventrally; mature achenes orbicular. ---------- 21. *C. brevior.*

Perigynia narrower, tapering into the beak, submembranaceous, usually nerved ventrally; achenes suborbicular. ------ 22. *C. molesta.*

Perigynia flat and thin, nearly translucent, 5.5-6.5 mm. long, finely nerved ventrally. ---------- 23. *C. Bicknellii.*

19. CAREX SCOPARIA Schkuhr; Willd. Sp. Pl. 4:230. 1805.
Wet prairies and swamps. Eastern half of state.

Clay Co., Clay Center, *C. Weber* 279. Cloud Co., *S. V. Fraser* 23. Douglas Co., Lawrence, *F. Agrelius*, July 11, 1910 (T). Linn. Co., Pleasanton, *Rydberg & Imler* 82 (U). Saline Co., three miles west of Brookville, *J. Hancin* 1505. Washington Co., Linn, *T. C. Dodd, Jr.* in 1933.

20. CAREX NORMALIS Mackenzie, Bull. Torr. Bot. Club 37:244. 1910.
C. mirabilis Dewey 1836; not Host, 1809.

Openings in woods. Eastern.
Wyandotte Co., woods, Quindaro, *K. K. Mackenzie*, May 30, 1897.

21. CAREX BREVIOR (Dewey) Mackenzie; Lunell, Am. Midl. Nat. 4:235. 1915.

C. straminea var. *brevior* Dewey.

C. festucacea var. *brevior* (Dewey) Fernald.

Prairies and dry, open woods. Throughout.

Barton Co., *A. S. Hitchcock*, August 1895. Brown Co., *M. E. Lands*, in 1896. Chatauqua Co., *A. S. Hitchcock*, May 7, 1897. Cherokee Co., *A. S. Hitchcock*, May 1896. Clay Co., *A. S. Hitchcock*, July 1895. Cloud Co., Concordia, *A. S. Hitchcock*, June 17, 1897; *S. V. Fraser* 24 and 35. Decatur Co., Jennings, *A. S. Hitchcock*, June 1892. Edwards Co., *A. Finch*, May 1932 and May 1933. Ellis Co., boggy places, Smoky River, *E. Bartholomew*, May 23, 1931. Ford Co., Bucklin, *A. S. Hitchcock*, July 1892. Geary Co., *A. S. Hitchcock*, June 1896. Harvey Co., *L. Herrick*, August 1898; prairie west of Newton, *F. C. Gates* 15188. Marshall Co., Irving, *H. F. Guthrie*, June 11, 1882. Mitchell Co., Beloit, *A. S. Hitchcock*, June 18, 1897. Morris Co., White City, *S. J. Norton*, May 17, 1893. Osborne Co., Natoma, *C. Weber* 84, 118 (in part) and 188. Ottawa Co., *A. S. Hitchcock*, May 10, 1897; *M. H. Panton* 66. Phillips Co., *A. S. Hitchcock*, June 29, 1897. Pottawatamie Co., *G. L. Clothier*, July 27, 1892. Rawlins Co., *A. S. Hitchcock*, June 1897. Republic Co., Courtland, *A. S. Hitchcock*, without date. Riley Co., Manhattan, *W. A. Kellerman* in 1889; Manhattan, *J. B. S. Norton*, May 19, 1894 and May 16, 1895; Manhattan, C. *O. Johnston* 72; prairie near Wild Cat, *M. Mather*, May 1928. Rooks Co., Rockport, *E. Bartholomew*, June 4, 1889. Sedgwick Co., M. A. Carleton, May 20, 1889; *M. Aquinas*, April 30 (S), May 9 (S), and June 6, 1933 (S); without collector, June 11, 1933 (U). Shawnee Co., *Norton & Clothier*, July 4, 1895; *B. B. Smyth* 862½; Topeka, B. B. Smyth, May 1895. Sheridan Co., *A. S. Hitchcock*, June 21, 1897; *C. Weber* 12, 405 and 262. Sherman Co., Goodland, *A. S. Hitchcock*, June 26, 1892. Smith Co., *A. S. Hitchcock*, June 28, 1897. Stafford Co., ditch west of Stafford, *F. C. Gates* 15152. Wabaunsee Co., *Norton & Carleton*, July 1894. Wilson Co., Roper, *W. H. Haller*, May 26, 1896. Woodson Co., *Clothier & Whitford*, August 29, 1897. Wyandotte Co., frequent in dry soil, Rosedale, *K. K. Mackenzie*, May 31, 1897.

22. CAREX MOLESTA Mackenzie, North American Flora 18:151. 1931.

Open, sunny places. Eastern half of state.

Douglas Co., *F. H. Snow* 3329 (U); Lawrence, *F. Agrelius*, April 20, 1910 (T). Leavenworth Co., *A. S. Hitchcock*, May 1896. Lyon Co., *F. Agrelius*, June 4, 1930 (T). Osborne Co., moist ditch, Downs, *C. Weber* 118 (in part). Riley Co., Manhattan, *G. Clark* in 1894. Sedgwick Co., *M. Aquinas*, June 11, 1933 (S). Shawnee Co., Topeka, *B. B. Smyth* 865 and 868. Wyandotte Co., around swamp near Argentine, *K. K. Mackenzie*, June 7, 1896; dry grounds, frequent, Quindaro, *K. K. Mackenzie*, May 30, 1897 (cotype).

23. CAREX BICKNELLII Britton. & Brown, Ill. Fl. 1:360. 1896.

Dry, usually open and grassy, places. Probably throughout; more common eastward.

Cherokee Co., *A. S. Hitchcock* 870. Douglas Co., *D. C. Brown*, May 27, 1899; Lawrence, *F. Agrelius*, April 20, 1910 (T); *F. H. Snow* 3329 (U). Leavenworth Co., *A. S. Hitchcock*, May 1896. Lyon Co., *F. Agrelius*, June 4, 1930 (T). Riley Co., Manhattan, *R. C. Wells*, May 20, 1892. Saline Co., roadside, *J. Hancin* 937. Sedgwick Co., *M. Aquinas*, April 30, 1933 (U; S). Shawnee Co., Topeka, *B. B. Smyth*, May 1, 1895, July 1896, and June 1898. Sherman Co., Goodland, *B. B. Smyth*, July 30, 1892. Wabaunsee Co., cemetery east of Wabaunsee, *P. Maus* 232.

*24. CAREX TRIBULOIDES Wahl. Sv. Vet. Akad.-Nya Handl. 24:145. 1803.

Swampy grounds. Eastern.

Wyandotte Co., common near Argentine, *K. K. Mackenzie*, June 7, 1896.

25. CAREX MUSKINGUMENSIS Schwein. Ann. Lyc. N. Y. 1:60. 1824.

C. arida Schwein. and Torr. 1825.

Low woods and thickets. Eastern.

Wyandotte Co., swampy ground near Argentine, very local. *K. K. Mackenzie*, June 7, 1896.

Section VII. PHYLLOSTACHYAE.

26. CAREX JAMESII Schwein. Ann. Lyc. N. Y. 1:67. 1824.

C. Steudelii Kunth. 1837.

Rich, wooded slopes. Eastern.

Douglas Co., Lawrence, *M. A. Carleton*, May 19, 1892. Leavenworth Co., *A. S. Hitchcock*, May 1896. Shawnee Co., Topeka, *E. A. Popenoe*, May 2, 1879. Wyandotte Co., common in rick woods, Quindaro, *K. K. Mackenzie*, May 30, 1897.

Section VIII. MONTANAE.

Perigynium-body (excluding stipitate base and beak) much longer than wide; staminate spike slender, 1.25-2 mm. wide; plant without long stolons. 27. *C. artitecta.*

Perigynium-body suborbicular; staminate spike stout, 3-6 mm. wide; plant with long stolons. ----------28. *C. heliophila.*

27. CAREX ARTITECTA Mackenzie, N. Am. Fl. 18:189. 1935.

C. varia Muhl. 1803; not Lumnitzer, 1791.

Dry, open woods and borders of thickets. Eastern half of state.

Douglas Co., *F. Agrelius*, March 25 and 26, 1910 (T). Leavenworth Co., *A. S. Hitchcock*, May 1896. Montgomery Co., Independence, *A. S. Hitchcock*, May 9, 1897. Pottawatomie Co., woods, *A. S. Hitchcock* 868. Riley Co., Manhattan, *W. A. Kellerman*, 126 and May 6, 1887; Papaw Glen, near Manhattan, *F. C. Gates* 11311; woods along Wild Cat Creek west of Manhattan, *F. C. Gates* 11323. Sedgwick Co., *M. Aquinas*, April 15, 1933 (U; S). Wyandotte Co., Argentine, *M. Reed*, April 1890 and April 30, 1891.

28. CAREX HELIOPHILA Mackenzie, Torreya 13:15. 1913.

C. pennsylvanica var. *digyna* Böck.

Prairies. Known from eastern half of state but probably occurs throughout.

Atchison Co., *E. B. Knerr*, May 1897. Clay Co., near Clay Center, *C. Weber* 402. Cloud Co., *S. V. Fraser* 25. Nemaha Co., Wetmore, *A. M. Nissen*, May 12, 1888. Ottawa Co., Dakota sandstone, Chapman Twp., *M. H. Panton* 44. Pottawatamie Co., sandy hill top north of Garrison, *F. C. Gates* 17090. Republic Co., Scandia, without collector, April 16, 1925. Riley Co., Manhattan, *W. A. Kellerman*, May 2, 1888; prairie, *J. B. Norton* 552a. Saline Co., meadow, *J. Hancin* 886. Sedgwick Co., Wichita, *M. A. Carleton*, April 27, 1889.

Section IX. TRIQUETRAE.

29. CAREX HIRTIFOLIA Mackenzie, Bull. Torr. Bot. Club 37:244. 1910.

C. pubescens Muhl. 1805; not Poir. 1789.

Dry woods and thickets. Eastern.

Wyandotte Co., Quindaro, *K. K. Mackenzie*, May 30, 1897.

Section X. Paniceae.

30. Carex Meadii Dewey, Am. Jour. Sci. 43:90. 1842.

C. tetanica var. *Meadii* L. H. Bailey.

Low, open grounds, usually on prairies. Chiefly eastern half of state.

Atchison Co., *E. B. Knerr*, May 1897. Chase Co., *M. A. Carleton*, May 7, 1888. Cherokee Co., *A. S. Hitchcock*, May 7, 1897. Clay Co., near Clay Center, *C. Weber* 406. Cloud Co., *S. V. Fraser* 26. Douglas Co., *A. S. Hitchcock*, July 6, 1899; Lawrence, *F. Agrelius*, (T). Geary Co., *A. S. Hitchcock*, June 1896. Montgomery Co., Independence, *A. S. Hitchcock*, May 9, 1897; *B. B. Smyth*, May 22, 1913. Morris Co., White City, *S. J. Norton*, May 17, 1893. Ottawa Co., Chapman Twp., *M. H. Panton* 43. Riley Co., Manhattan, *W. A. Kellerman*, May 2, 1888; *M. A. Carleton*, May 7, 1892; Manhattan, *G. R. Evans*, May 5, 1894; wet places, *J. B. Norton* 559; swampy prairie, Wild Cat, *M. Mather*, May 1928. Saline Co., meadow, *J. Hancin* 869, 901 and 928. Sedgwick Co., *M. Aquinas*, May 9, 1933 (S). Shawnee Co., Topeka, *B. B. Smith* 775 and May 1892. Sheridan Co., *C. Weber* 406 (in part). Wabaunsee Co., *J. M. Westgate*, May 2, 1898. Washington Co., northwest of Linn, *T. C. Dodd, Jr* 151.

Section XI. Laxiflorae.

31. Carex blanda Dewey, Am. Jour. Sci. 10:45. 1825.

C. laxiflora var. *blanda* (Dewey) Boott.

C. laxiflora var. *varians* L. H. Bailey.

Woods. Eastern half of state.

Atchison Co., *E. B. Knerr*, May 1897. Bourbon Co., Fort Scott, *A. S. Hitchcock*, May 1897. Chautauqua Co., *A. S. Hitchcock*, May 7, 1897. Cherokee Co., woods, *A. S. Hitchcock*, in 1896; woods southeast of Monmouth, *A. A. Jacobs* 22. Douglas Co., moist grounds, Lawrence, *W. C. Stevens*, July 1892; *Z. D. E. Brown*, July 6, 1896; Lawrence, *F. Agrelius*, May 7, 1909 (T); *F. H. Snow* 3267 (U). Leavenworth Co., *A. S. Hitchcock*, May 1896. Osborne Co., rich creek bank, *C. Weber* 459. Pottawatomie Co., St. George, *A. S. Hitchcock*, May 2, 1896. Riley Co., Manhattan, *W. A. Kellerman*, May 1 and 10, 1888; Manhattan, *G. Zeigler*, May 28, 1892; Manhattan, *F. Morgan*, May 1892; Manhattan, *L. Mann* in 1894; low ground near Wild Cat, *M. Mather*, without date. Saline Co., woods along Dry Creek, *J. Hancin*, 924. Sedgwick Co., *M. A. Carleton*, May 25, 1889; *M. Aquinas*, April 22 and May 10, 1933 (S). Shawnee Co., Topeka, *B. B. Smyth*, June 1892 and June 1898. Wabaunsee Co., *C. L. Clothier*, May 1897. Wyandotte Co., Argentine, *M. Reed*, May 1890; Quindaro, *A. S. Hitchcock*, May 3, 1897; woods, Quindaro, *K. K. Mackenzie*, May 30, 1897; low ground, Muncy, *K. K. Mackenzie* 27.

Section XII. Granulares.

Rootstocks not long-creeping; staminate spike short-peduncled or sessile; two upper pistillate spikes usually contiguous.

Perigynia broadly ovoid to broadly obovoid, 2.5-4 mm. long, 1.5-2.5 mm. wide, soon ventricose-squarrose, tapering at apex, minutely beaked. 32. *C. granularis.*

Perigynia elliptic-obovoid to elliptic-ovoid, 2-2.5 mm. long, 1.5 mm. wide., ascending, not ventricose-squarrose, rounded at apex, abruptly beaked. ---------- 32a. *C. granularis* var. *Haleana.*

Rootstocks long creeping; staminate spike long-peduncled; spikes widely separate.

Perigynia nerved, 3-3.5 mm. long, very short-beaked, the orifice entire or minutely bidentulate; pistillate spikes 5-6 mm. wide; leaf-blades 1.5-3 mm. wide. ---------- 33. *C. Crawei.*

Perigynia ribbed, 3-4.5 mm. long, the beak short but conspicuous, the orifice bidentulate; pistillate spikes about 7.5 mm. wide; leaf-blades 3-6 mm. wide. ----------34. *C. microdonta.*

32. CAREX GRANULARIS Muhl.; Willd. Sp. Pl. 4:279. 1805.

Moist meadows. Eastern.

Wyandotte Co., common around Argentine swamp, *K. K. Mackenzie*, June 7, 1896.

32a CAREX GRANULARIS Muhl., var. HALEANA (Olney) Porter, Proc. Acad. Phila. 1887:74. 1887.

C. Haleana Olney, 1871.
C. granularis var. *Shriveri* Britton, 1896.
C. Shriveri Britton, 1901.

Moist meadows. Eastern.

Riley Co., Manhattan, *J. B. Norton*, June 1896.

33. CAREX CRAWEI Dewey, Am. Jour. Sci. II. 2:246. 1846.

Moist open places, usually in sandy or sterile soil. Very local.

Shawnee Co., Topeka, *B. B. Smyth*, July 1897.

*34. CAREX MICRODONTA Torr. & Hook.; Torr. Ann. Lyc. N. Y. 3:423. 1836.

Wet prairies. Southern.

Chautauqua Co., low ground, *A. S. Hitchcock* 1021 (May 7, 1897). Montgomery Co., Independence, *A. S. Hitchcock*, May 9, 1897.

Section XIII. OLIGOCARPAE.

35. CAREX OLIGOCARPA Schhkuhr; Willd. Sp. Pl. 4:279. 1805.

Rich woods and thickets. Eastern.

Riley Co., woods, *J. E. Payne* 1022; low woods, *J. B. Norton* 556. Wyandotte Co., woods, Quindaro, *K. K. Mackenzie*, August 30, 1897.

Section XIV. GRISEAE.

36. CAREX GRISEA Wahl. Sv. Vet.-Akad. Nya Handl. 24:154. 1803.

Woods and borders of thickets in meadows. Chiefly eastern half of state.

Clay Co., Clay Center, *C. Weber* 15 and 17. Cloud Co., Concordia, *A. S. Hitchcock*, June 17, 1897; *S. V. Fraser* 27. Dickinson Co., *A. S. Hitchcock*, June 1896. Geary Co., moist grassland, *R. H. Imler*, May 29, 1929 (U). Leavenworth Co., *J. Wherrell* 3257 (U). Montgomery Co., Independence, *A. S. Hitchcock*, May 9, 1897. Osborne Co., moist woods, *C. Weber* 309. Ottawa Co., *M. H. Panton* 167. Riley Co., meadow near Wild Cat, *M. Mather*, May 1929; creek valley, *R. H. Imler*, May 28, 1929 (U). Saline Co., in woods along Dry Creek, *J. Hancin* 228 and 923. Sumner Co., wooded Chickasha River bottoms, *F. C. Gates* 15176. Wabaunsee Co., wet pasture ravine northeast of Keene, *P. Maus*, May 29, 1927. Washington Co., northwest of Linn, *T. C. Dodd, Jr.* in 1932. Wyandotte Co., rich woods, Quindaro, *K. K. Mackenzie*, May 30, 1897.

Section XV. GRACILLIMAE.

37. CAREX DAVISII Schwein. & Torr., Ann. Lyc. N.Y. 1:326. 1825.

Alluvial woodlands. Eastern third of state.

Douglas Co., Lawrence, *M. A. Carleton*, May 19, 1892; Lawrence, *F. Agrelius*, June 1, 1910 (T); *F. H. Snow* 3227 (U). Leavenworth Co., *A. S. Hitchcock*, May

1896. Riley Co., Manhattan, *W. A. Kellerman*, July 1888; Manhattan, *G. Clark* in 1894; wet soil, *J. B. Norton* 866; meadow near Wild Cat, *M. Mather*, May 1925. Shawnee Co., Topeka, *B. B. Smyth*, May 1891 and May 1895; Topeka, *M. A. Carleton* 15. Wyandotte Co., low grounds, Rosedale, *K. K. Mackenzie*, May 4, 1895.

Section XVI. Virescentes.

Perigynia markedly flattened ventrally, rounded at apex, nerved, about 2.25 mm. long; pistillate scales short-cuspidate to obtuse. ----------38. *C. hirsutella.*

Perigynia turgid, nearly terete, short-pointed at apex, coarsely nerved or ribbed, 2.5-3.5 mm. long; pistillate scales long-acuminate, cuspidate or awned, sparingly pilose. ----------39. *C. Bushii.*

*38. Carex hirsutella Mackenzie, Bull. Torr. Bot. Club 50:349. 1923.

C. hirsuta Willd., 1805; not Suter, 1802.
C. triceps var. *hirsuta* (Willd.) L. H. Bailey, 1889.

Dry open woods and meadows. Eastern.
Cherokee Co., woods, *A. S. Hitchcock* 871.

39. Carex Bushii Mackenzie, Bull. Torr. Bot. Club 37:241. 1910.
Meadows and low, open woods. Eastern half of state.

Cherokee Co., *A. S. Hitchcock*, May 1896 and May 7, 1897. Clay Co., near Clay Center, *C. Weber* 403. Cloud Co., *S. V. Fraser* 28. Douglas Co., *F. Agrelius*, May 31 and July 12, 1910 (T).

Section XVII. Hirtae.

40. Carex lanuginosa Michx. Fl. Bor. Am. 2:175. 1803.

C. filiformis var. *latifolia* Böck.
C. filiformis var. *lanuginosa* BS.P.
C. lanuginosa var. *kansana* Britton.

Open swampy places. Probably throughout.

Clay Co., near Clay Center, *C. Weber* 404. Cloud Co., *M. A. Carleton*, May 31, 1888; *S. V. Fraser* 30. Decatur Co., *A. S. Hitchcock*, June 2, 1897. Douglas Co., *F. H. Snow* 3266 (U); Lawrence, *F. Agrelius*, April 20 and May 31, 1910 (T). Ellis Co., in swamp, Saline River, *E. Bartholomew* 1196. Graham Co., *A. S. Hitchcock*, June 20, 1897. Montgomery Co., Independence, *A. S. Hitchcock*, May 9, 1897. Reno Co., sand dunes, Medora, *F. C. Gates* 17106. Riley Co., Manhattan, *W. A. Kellerman*, May 16, 1888; *J. B. Norton* 555; prairie east of Manhattan, *G. R. Crawford*, May 12, without year. Rooks Co., Rockport, *E. Bartholomew*, May 25, 1889. Saline Co., wet pasture 7 miles southeast of Salina, *J. Hancin* 885; "Gaumer Springs" near Hallville, *J. Hancin* 915. Shawnee Co., Topeka, *B. B. Smyth* 711 and 712. Sherman Co., Goodland, *F. Agrelius*, July 28, 1911 (T). Sheridan Co., *C. Weber* 13, 269 and 406 (in part). Washington Co., northwest of Linn, *T. C. Dodd, Jr.* 150.

Section XVIII. Shortianae.

41. Carex Shortiana Dewey, Am. Jour. Sci. 30:60. 1836.
Moist woodlands and thickets. Eastern

Leavenworth Co., woods, *A. S. Hitchcock* 869. Wyandotte Co., common in low grounds, Quindaro, *K. K. Mackenzie*, May 30, 1897.

Section XIX. ACUTAE.

Perigynia strongly ribbed, the beak markedly bidentate; culms strongly phyllopodic (i.e. the lowermost leaves with well-developed blades)_____ 42. *C. nebraskensis.*

Perigynia not ribbed, the beak minutely emarginate or entire; culms strongly aphyllopodic (i.e. the lowermost leaves bladeless). _____43. *C. Emoryi.*

42. CAREX NEBRASKENSIS Dewey, Am. Jour. Sci. II. 18:102. 1854.

C. Jamesii Torr., 1836; not Schwein., 1824.

Low meadows and plains. Western.

Cheyenne Co., low ground, *A. S. Hitchcock* 1023.

43. CAREX EMORYI Dewey, in Torr. Bot. Mex. Bound. Surv. 230. 1859.

C. stricta var. *Emoryi* (Dewey) Bailey, 1886.

Swampy meadows and river banks. Represented from eastern two thirds of state; probably occurs throughout.

Cloud Co., *S. V. Fraser* 29. Douglas Co., *Z. D. E. Brown*, May 27, 1899; Lawrence, *F. Agrelius*, April 20, 1910 (T). Leavenworth Co., *A. S. Hitchcock*, May 1896. Osborne Co., *C. Weber* 12. Pottawatomie Co., St. George, *A. S. Hitchcock*, April 1895. Reno Co., Hutchinson, *F. Agrelius*, April 20, 1910 (T). Riley Co., Manhattan, *H. Olson*, May 24, 1894; wet places, *J. B. Norton* 553. Rooks Co., *E. Bartholomew*, July 1889. Saline Co., river bank, near water's edge, in Oakdale Park, *J. Hancin* 881. Sedgwick Co., *M. A. Carleton*, May 9, 1888. Wabaunsee Co., *J. M. Westgate*, May 2, 1898; moist grounds north of Harveyville, *P. Maus* 233.

Section XX. PSEUDO-CYPERAE.

44. CAREX HYSTRICINA Muhl., Willd. Sp. Pl. 4:282. 1805.

Swamps and wet meadows. Throughout.

Clay Co., Clay Center, *C. Weber* 82. Cloud Co., *S. V. Fraser* 32. Decatur Co., *A. S. Hitchcock*, June 2, 1897. Doniphan Co., *Hall, Lovejoy & Maroney*, August 19, 1913 (U). Douglas Co., Lawrence, *M. A. Carleton*, June 24, 1892. Ellsworth Co., Wilson, *C. Weber* 20. Pottawatomie Co., St. George, *J. B. S. Norton*, May 24, 1894. Rooks Co., *E. Bartholomew*, May 25, 1890. Riley Co., Manhattan, *Smith & Norton*, August 30, 1892; Manhattan, *J. B. Dorman* in 1893; wet places, *J. B. Norton* 554. Saline Co., wet pasture 4 miles east of Assaria, *J. Hancin* 913. Shawnee Co., Topeka, *B. B. Smyth* in 1897. Sheridan Co., *A. S. Hitchcock*, June 21, 1897; *C. Weber* 14 and 268. Sherman Co., Goodland, *F. Agrelius*, August 1, 1911 (T). Trego Co., *A. S. Hitchcock*, July 1895. Wabaunsee Co., Alma, *Norton & Carleton*, July 14, 1893; *Norton & Clothier*, July 3, 1895; wet ravine east of Wabaunsee, *P. Maus* 229. Washington Co., northwest of Linn, *T. C. Dodd, Jr.* 28. Wilson Co., Roper, *W. H. Haller*, June 4, 1896.

Section XXI. PALUDOSAE.

Teeth of perigynium-beak short (0.5 mm. long), erect; mature perigynia impressed-nerved. _____45. *C. hyalinolepis.*

Teeth of perigynium-beak long (1-2 mm.), ascending or spreading; perigynia strongly many-ribbed. _____46. *C. laeviconica.*

45. CAREX HYALINOLEPIS Steud. Syn. Cyp. 235. 1855.

C. lacustris var. *laxiflora* Dewey.
C. riparia var. *impressa* S. H. Wright.
C. impressa (S.H. Wright) Mackenzie.

Open swamps. Eastern.

Douglas Co., *Z. D. E. Brown*, May 23, 1899; *F. H. Snow* 3311 (U); *F. Agrelius*, May 6, May 14 and June 1, 1910 (T). Leavenworth Co., *A. S. Hitchcock*, May 1896. Wyandotte Co., Argentine swamp, *K. K. Mackenzie*, April 26, 1896; low ground, Quindaro, *K. K. Mackenzie*, May 30, 1897.

46. CAREX LAEVICONICA Dewey, Am. Jour. Sci. II. 24:47. 1857.

C. aristata var. *longo-lanceolata* Dewey.
C. trichocarpa var. *imberbis* A. Gray, in part.

Marshes. Eastern half of state.

Clay Co., Clay Center, *C. Weber* 405. Cloud Co., Gen. Grant (?), May 24, 1888; without collector, May 24, 1888 (U); *S. V. Fraser* 31. Pottawatomie Co., St. George, *W. A. Kellerman*, May 20, 1891. Riley Co., Manhattan, *W. A. Kellerman*, May 10, 1888; wet places, *J. B. Norton* 560; Manhattan, *S. Evans*, May 27, without year. Saline Co., *J. Hancin* 938.

Section XXII. SQUARROSAE.

47. CAREX FRANKII Kunth, Enum. Pl. 2:498. 1837.

C. stenolepis Torr. 1836; not Less. 1831.

Wet meadows and swamps. Eastern third of state.

Anderson Co., *A. S. Hitchcock*, July 1896. Bourbon Co., *Clothier & Whitford*, August 11, 1897. Cherokee Co., *Clothier & Whitford*, August 14, 1897; prairie south of Monmouth, *A. A. Jacobs* 87. Coffey Co., *Clothier & Whitford*, August 31, 1897. Crawford Co., *A. A. Jacobs*, June 26, 1931. Douglas Co., *F. H. Snow* 3325 (U); Lawrence, *F. Agrelius*, June 25, 1910 (T). Franklin Co., *A. S. Hitchcock*, August 1896. Johnson Co., *Clothier & Whitford*, August 7, 1897. Labette Co., *A. S. Hitchcock*, August 1896. Linn Co., *Clothier & Whitford*, August 9, 1897; *Rydberg & Imler*, June 20, 1929; roadside between Pleasanton and Prescott, *Rydberg & Imler*, 114 (U). Montgomery Co., roadside ditch, *W. H. Horr*, July 5, 1930 (U). Morris Co., *J. B. S. Norton*, July 30, 1895. Neosho Co., *A. S. Hitchcock*; August 1896; lowlands, *W. H. Horr*, July 5, 1929 (U). Shawnee Co., Topeka, *B. B. Smyth*, June 1902. Wilson Co., Roper, *W. H. Haller*, June 4, 1896; wet soil, *W. H. Haller* 865. Wyandotte Co., low grounds, Quindaro, *K. K. Mackenzie*, June 21, 1896.

Section XXIII. LUPULINAE.

48. CAREX LUPULINA Muhl.; Willd. Sp. Pl. 4:266. 1805.

Swamps. Eastern.

Labette Co., Oswego, *W. S. Newton*, August 25, and Sept. 1890. Wyandotte Co., Argentine swamp, *K. K. Mackenzie*, June 7, 1896.

EXCLUDED SPECIES

Mackenzie reports *Carex atherodes* Spreng. (N. Am. Fl. 18:439. 1935.) and *C. mesochorea* Mackenzie (as *C. mediterranea* Mackenzie, Bull. Torr. Bot. Club 33:441. 1906.) as occurring in Kansas. Both of these may occur within the state but the writer has been unable to locate any Kansas specimens of them.

Rydberg (Flora of the Prairies and Plains, p. 174. 1932.) includes Kansas within the range of *C. xerantica* Bailey, a more northern and western species not likely to be found here.

Britton (Manual of the Flora of the Northern States and Canada, 1901.) ascribes *C. castanea* Wahl. to Kansas (p. 206), a species having a much more northeastern range, and also *C. filifolia* Nutt. (p. 217) which might come into the northwestern counties.

I am indebted to Dr. Gates for bringing to my attention the Provisional Catalogue of the Flora of Kansas-II (Trans. Kansas Acad. Sci. 25: 63-128. 1913.) in which the following species are reported:

534. *C. gigantea* Rudge
535. *C. utriculata* Boott (=*C. rostrata* Stokes).
536. *C. monile* Tuckerm.
537. *C. lurida* Wahl.
539. *C. squarrosa* L.
541. *C. trichocarpa* Muhl.
543. *C. riparia* Curtis (=*C. lacustris* L.)
565. *C. Douglasii* Boott
570. *C. diandra* Schrank.
575. *C. Muhlenbergii* Schkuhr
547. *C. stricta* Lam.
555. *C. tetanica* Schkuhr
557. *C. laxiflora* Lam.
558. *C. platyphylla* Carey
559. *C. setifolia* Britt. (=*C. eburnea* Boott.)
560. *C. pennsylvanica* Lam.
562. *C. umbellata* Schkuhr
580. *C. straminea* Willd.
582. *C. festucacea* Willd.

Of these *C. trichocarpa, C. lacustris, C. stricta, C. laxiflora, C. pennsylvanica, C. Muhlenbergii, C. straminea* and *C. festucacea* probably represented other, related, species since either the species themselves or the application of the names have been subsequently reinterpreted.

All of the above species are excluded because no specimens could be found to authenticate the records.

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A Preliminary Vegetation Map of Indiana *

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Introduction

During the summer of 1928, while engaged in a study of forest plantings in Indiana, under the direction of the Central States Forest Experiment Station, the writer had an opportunity to observe a majority of the vegetation types of this state. The classification used followed that of Transeau and Sampson (1927, 1928) for Ohio, with such modifications and additions as seemed necessary to fit local conditions. Nearly every physiographic region was visited then or subsequently, and field notes were used to prepare a reconnaissance map of the major vegetation areas. The physiographic regions mentioned in this report follow the classification by C. A. Malott (1922). Information concerning the distribution of certain indicator species was obtained from the publications of Charles C. Deam (1921, 1924, 1929). A copy of a "Proposed Type Classification of Indiana Forests" by George R. Phillips was furnished to the writer by R. F. Wilcox, who was then acting State Forester. The writer wishes to acknowledge his indebtedness to the above-mentioned persons and to the following for information and valuable advice: E. F. McCarthy, L. F. Kellogg, H. F. Thut, B. S. Meyer, A. G. Chapman, T. M. Bushnell, E. Lucy Braun, and Dorothy Parker; especially to E. N. Transeau for reading and constructive criticism of the manuscript and accompanying map.

Preliminary copies of the map were sent for criticism to the following botanists: C. C. Deam, E. Lucy Braun, A. G. Vestal, H. C. Hanson, R. C. Friesner, Stanley A. Cain, B. H. Smith, and J. A. Nieuwland. Published reports of the Bureau of Soils, the Indiana Department of Conservation, and the Purdue University Agricultural Experiment Station furnished certain valuable clews to the nature of areas not visited by the writer. Occasional articles in the Proceedings of the Indiana Academy of Science, the Butler University Botanical Studies, and the American Midland Naturalist contain descriptions of interesting areas of vegetation where detailed studies have been made by Indiana botanists. (See bibliography).

Method

The reconnaissance survey-method used in Ohio by Transeau and Sampson was found to be most suitable for preparing the preliminary vegetation map of Indiana. This method grew out of studies of local forests in various parts of the state over a period of ten years. These studies indicated that there were several basic vegetation types and a number of variants of each

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type. The major types lend themselves to reconnaisance mapping on a scale necessary for a state map. On county maps, on the other hand, many of the variant types may be separated and displayed effectively. On the first published map of Ohio (Transeau and Sampson, 1935) only four major types; prairie, swamp forest, beech-maple, and oak-hickory, have been separated. On the unpublished maps of some twenty counties about six times this number of types have been distinguished. The latter of course more nearly approach the plant association as commonly defined. After a thorough sampling of the best remnants in a local physiographic division it is quite possible to map the surrounding or intervening areas with considerable confidence.

1. Using principles of physiographic ecology first outlined in this country by H. C. Cowles, observations are made on the relation of major communities or plant associations to physiographic conditions.

2. Reconnaissance trips are made by automobile, two persons traveling together, one to drive and the other to make observations and take notes. Observations made from the machine are recorded, along with mileage and route, so that the notes may later be used to plot information thus obtained on a map. The topographic sheets of the U. S. Geological Survey are best for this purpose and when such maps are obtainable, notations are made directly on the map. Abbreviations such as B-M, O-H, and S-F are used for beech-maple, oak-hickory, and swamp forest types respectively. These types are mappable and may be recognized by an experienced worker through the occurrence of certain indicator trees. The form, branching, profile, and color of foliage or bark may be recognized even at a distance of a quarter of a mile.

3. Whenever an important change is noted in the vegetation, such as may occur when a major physiographic boundary is crossed, stops are made for close observation of representative mature vegetation. After the type is determined by such observation, characteristic indicator species are picked out which can be readily recognized from a distance, and these are used as a guide to the type-mapping from the road. Attempts are made to cross and re cross major vegetation boundaries to determine their extent.

4. Use is made of soil maps and geological maps in determining important natural boundaries. Soil maps are especially useful because there is usually a change in relative amount of certain soil types to correspond with a change in the character of the vegetation. These maps must be used with care and with a thorough appreciation of the basis on which soil types are determined. Frequently it is possible to find the same or nearly the same vegetation type on several soil types, as Sampson observed in Marion County, Ohio (Sampson, 1930c, d). Unfortunately soil maps are not available for every county and those made before 1910 are practically worthless, except to show drainage, culture, and certain physiographic boundaries. The notations as to vegetation found on various soils are often misleading, since no apparent account is made as to whether the vegetation observed was primary or second-

ary. All too often, secondary vegetation is very different from the primary. For instance, hickory and oak groves may be found to-day where the original vegetation was forests of elm, ash, and beech. Improved drainage, clear cutting, selective cutting, grazing, and fires may totally change the character of the forest vegetation.

5. A large crayon sketch map was prepared, using as a base the drainage map of Indiana published by the Indiana Department of Conservation. Different colors were used to represent the different major types of vegetation. This original map was checked for possible errors by Charles C. Deam and others. An old atlas of Indiana, published in 1876 was used to determine the boundaries of prairies and forests, mostly in the northern counties. The printing of the larger map in colors appears too costly at present, and so a smaller black-line map was prepared for this publication.

6. Several interpolations were necessary, since the writer did not have the opportunity to travel in all of the counties of the state. However, these interpolations were made with due consideration of the physiography of the area involved and the soil and climatic conditions prevailing there. In other words, the well-known principles of physiographic ecology were again applied to produce a complete map. Detailed studies of individual counties are needed to verify the correctness of the boundaries. However, it serves its purpose if it stimulates further research in this very important field. Such research should be carried on preferably by local botanists who have some training in plant ecology so that they can recognize plant associations in relation to habitat conditions and vegetational history. A quadrangle or a county may be used as convenient unit for the more detailed work.

Classification of Major Vegetation Types

The major vegetation types recognized in the Indiana for purposes of this study are prairie grasslands, upland oak forests, northern swamp forests, beech forests, mixed mesophytic forest and segregates, beech-sweet gum forests of "The Flats," southern swamp forest and bald cypress forests. These major vegetation types or alliances are mappable by the reconnaissance method and can be further subdivided to include a number of well-recognized association types. An annotated list of association types to be recognized in detailed studies is presented below:

A. Prairie Grasslands

There is essentially no difference between the prairies of Benton County, Indiana and the "Grand Prairie" of Illinois which extends to the westward (Welch, 1930). Smaller prairies occur in other parts of the state as scattered sloughs or marshes in forested regions or as sand prairies in the oak-openings.

1. *Wet prairies or sloughs,* containing *Spartina michauxiana, Cacalia tuberosa, Asclepias incarnata, Lacinaria spicata,* and *Eryngium aquaticum.* Natural meadows of marsh hay *(Calamagrostis canadensis)* may be included.

2. *Mesophytic prairies*, containing *Andropogon furcatus, Sorghastrum nutans, Solidago rigida, Silphium terebinthinaceum, Helianthus giganteus, Meibomia canadensis*, etc.

3. *Dry prairies*, containing *Andropogon scoparius, Lacinaria scariosa, Lespedeza capitata, Tithymalopsis corollata, Silphium trifoliatum, Coreopsis tripteris*, etc.

B. Upland Oak Forests

Phillips lists eight forest types containing oaks, and further subdivides his Mixed Oak Forests into six types. They are not all upland types however. The classification of oak forest types in the central states is admittedly a difficult task, because so many mixtures are met with in the field.

1. *Oak-Hickory*. (Figure 1). These are distinctly white oak-black oak-hickory associations, occurring on morainal ridges of sand and gravel in northeastern Indiana and on clay bluffs in the vicinity of the prairies. In northern Indiana they contain white oak, red oak, black oak, shingle oak, shagbark, pignut and bitternut hickories, with some red maple, black cherry, and sassafras. In southern Indiana, southern red oak, scarlet oak, post oak, mockernut hickory and flowering dogwood may occur in the mixture. (Potzger and Friesner, 1934).

2. *Oak-Maple*. These are more mesophytic forests than the oak-hickory and are characterized by the presence of white oak, red oak, hard maple, black walnut, white ash, shagbark hickory, basswood, and hackberry, sometimes with blue ash and yellow oak, particularly where the soils are derived from limestone. Black oak and sassafras are usually absent or scarce in the oak-maple types as distinguished from the oak-hickory.

3. *White Oak*. According to Chas. C. Deam, this type of forest was well developed along the banks of the Maumee and its tributaries in northeastern Indiana. According to Phillips it occurs "on clay ridges in all parts of Indiana when white oak predominates."

4. *White Oak-Black Oak*. This type, with little or no hickory, occurs in the oak-openings on sandy hummocks and gravelly ridges in northern Indiana. Phillips says that black oak predominates in these situations as well as on "barrens" of Harrison, Floyd and Washington counties.

C. Northern Swamp Forests

Several plant associations, which should be recognized in detailed county surveys, are included in this alliance. H. C. Sampson (1930a) has made a detailed analysis of deciduous swamp forests in Ohio and his classification of types can be followed in Indiana. He distinguishes three successional phases of the swamp forest in northern Ohio. In Indiana, the equivalent phases are as follows, in order of increased drainage requirements.

1. *Elm-black ash-soft maple.* (Figure 2). This type often contains cottonwood and sycamore as co-dominants.

2. *Bur oak-big shellbark hickory.* Co-dominants are white elm, black ash, white ash, and green ash, swamp white oak, pin oak, red maple and silver maple.

3. *Red oak-basswood.* Co-dominants are white elm, soft maple, white ash, white oak and shagbark hickory.

D. Beech Forests

For purposes of reconnaissance, this includes all types of forest containing a large percentage of beech *(Fagus grandifolia* Ehr.). The trees are readily recognized from a distance by their smooth light grey trunks and branches and the bronze-green or olive-green color of the foliage. The beech forests of Ohio, Indiana, and southern Michigan differ from those in western New York and northern Pennsylvania by the absence of conifers and birches. The latter belong to the Hemlock-White Pine-Northern Hardwood forest region recognized by Nichols (1935). In detailed surveys of Indiana vegetation, a distinction should be made among the following types containing beech.

1. *Beech sub-type.* (Figure 3). Over a large part of central Indiana, on the Tipton (Wisconsin) Till Plain, beech pure or predominant succeeded the swamp forests where drainage conditions were slightly improved. In some cases where pure stands of beech are to be found to-day, early selective cutting of white oak, bur oak, red oak, black cherry and yellow poplar occurred, followed by grazing. In these "woodlots" there is little or no reproduction of the more valuable commercial species, and the beeches show decadence in the form of "dry tops." Only a study of early land survey records or local history can be used to determine whether these pure stands of beech existed at the time of the pioneer white settlements or whether they represent a stand of suppressed or inferior species remaining after selective cutting of more valuable dominant hardwoods.

2. *Beech-Sugar Maple type.* In composition, Phillips remarks that this type is pure or mixed with white ash, yellow poplar, basswood, walnut, hickory and white oak. The writer would add black cherry and red oak to his list of co-dominants. Such forests occupy rich upland or well-drained alluvial soils along streams of central Indiana and the lower slopes of spurs in the "Knobs" of southern Indiana. In Central Indiana this should certainly be recognized as the climatic climax forest of the region (Esten, 1932). A climax forest is essentially a mature forest which has ceased to change in composition at least with regard to the dominant species. It is rather an abstract concept, with several examples in the Deciduous Forest Formation, including beech-maple, oak-maple, and oak-hickory types.

3. *Beech-Maple-Yellow Poplar sub-type.* In areas of light but moist and fertile soils, there may be a greater percentage of yellow poplar and red maple in the composition of the beech-sugar maple type. In detailed mapping of smaller areas, such as a county or a quadrangle, this sub-type is significant and should be recognized.

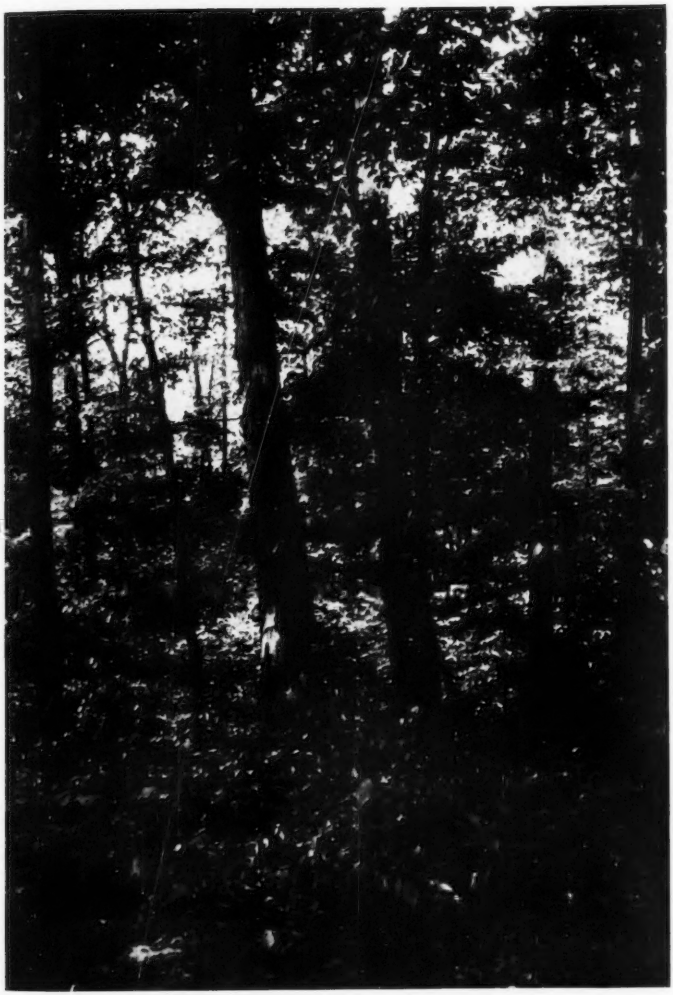

Fig. 1. Virgin Oak-Hickory Forest at Pokagon State Park, Indiana. Photo by R. B. Gordon. September 14, 1935.

E. Mixed Mesophytic Forest

Much of the "Knobs" country is mapped as mixed mesophytic forest. Beech, yellow poplar, white oak, sugar maple, red maple, black walnut, basswood, hickory, white ash, and northern red oak occur mixed in about equal proportion on the slopes. Chestnut, cucumber tree and bitternut may also be present. Variations in the composition account for a number of segregates as described by E. Lucy Braun (1935a, b). Some of these segregates approach very closely the oak-maple type which has previously been described. In fact, they may be nearly ecological equivalents, in spite of certain differences in composition.

H. C. Sampson (1930b) has made an ecological analysis of the mixed mesophytic forest community in Ohio. His charts show that "it appears to be a special type of transitional community occupying a position between dry sites covered by oak-chestnut and moist sites on which the complex of factors is favorable to the dominance of beech-maple."

This type should *not* be confused with one of the transition phases in the swamp forest community, in which red oak, basswood, yellow poplar, and black walnut may appear just before the advent of beech, white oak and hard maple, as the habitat becomes better drained. In spite of the seeming similarity in floristic composition, the better drained phases of the swamp forest cannot be regarded as the ecological equivalent of the mixed mesophytic forest.

In the "knobstone area" of southeastern Indiana, extending into Clark, Floyd, Scott, and southeastern Washington counties, the summits of the "Knobs" may be covered with forests of oaks, mixed with chestnut, and locally with scrub pine. Elsewhere, the "Knobs" are capped with oak-hickory forests. Mixed mesophytic forests occur on some of the slopes, with beech-maple-yellow poplar on the lower slopes of "spurs" and in the valleys. The north slopes may be covered with the beech-sugar maple forest. Mapping of such areas should be attempted only on a topographic base.

F. Beech-Sweet Gum Forests of "The Flats"

The Illinois Till Plain in southeastern Indiana is developed on the Muscatatuck Regional Slope, which averages about 15 feet to the mile. A peculiar series of forest types has developed on the poorly drained acid clay soils of this region. Principal co-dominants are pin oak, red maple, and swamp white oak. In restricted portions cow oak, river birch, black gum, and white oak bring about variations in composition which would be recognized in more detailed surveys. Dense stands of pin oak and sweet gum are now found as secondary forests where the original forests contained a considerable amount of beech.

G. Southern Swamp Forests

These are to be considered as extensions of a common type of vegetation throughout the Mississippi Embayment. They are located for the most part

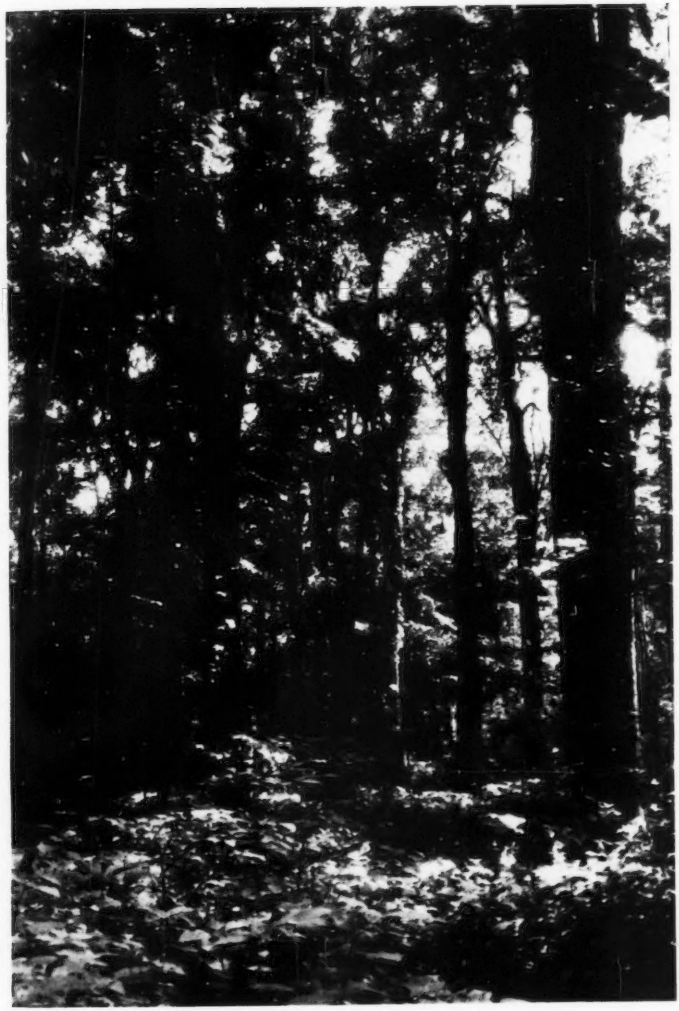

Fig. 2. Swamp Forest in Lucas County, Ohio. Similar forests occupied poorly drained areas in central and eastern Indiana. Photo by R. B. Gordon. Summer, 1927.

in southwestern Indiana, in the Wabash Lowland, or in general the region south of the glacial boundary west of the "Knobs." The elm-ash-maple association contains sweet gum, pin oak, Biltmore ash, black gum, cow oak, and river birch, with a scattering of winged elm, honey locust, white or mockernut hickory, and Mississippi hackberry. This is a characteristic type along some of the smaller streams and originally covered great areas now under cultivation.

Difficulties arise in classifying the forests of flood plains or bottomlands on account of the larger number of species involved, and on account of rapid physiographic changes. These changes affect local drainage conditions, destroy old habitats and create new ones. Close to the stream edge, in the newest portions of the flood plain, sycamores, willows, and river birch form a forest community, followed closely by soft maples, box elder, American elm, black gum and sweet gum. The next stage in succession, as the habitat becomes slightly better drained, might be designated as the sweet gum stage, in which cow oak, pumpkin ash, hackberry, pecan and winged elm appear. The third stage is characterized by an abundance of oaks in the forest, including pin oak, cow oak, shingle oak, swamp Spanish oak, and overcup oak, associated with sweet gum, black gum and shellbark hickory. The forest in this stage is fairly well stabilized and might be called the "sweet gum-swamp oak-hickory" type (Gordon, 1932).

H. Bald Cypress

Areas of cypress mixed with the "bottomland hardwoods" occur in the lower Wabash valley on broad fertile flood plains. Pure stands of cypress are found in the "back sloughs" such as Hovey Lake in Posey County (Cain, 1935). Twenty thousand acres in southern Knox County were once covered with a fine forest of cypress, according to Collett (1874), quoted by Deam (1921). These are the most northward extensions of the forests of cypress and tupelo which characterized the Mississippi Embayment. In no case is cypress found as a native tree north of the glacial boundary in Indiana.

I. Relic Associations

1. *Hemlock* is found in a few scattered localities in the "Knobs," reported from Brown, Jackson, Lawrence, and Jennings counties in southern Indiana. Only a few trees occur in each of these localities. Along Sugar Creek, in Fountain and Montgomery counties, hemlock is more frequent. Good stands are to be seen at Turkey Run State Park and at "The Shades" in Montgomery County. These stations are deep gorges or sandstone bluffs with a north exposure (Daubenmire, 1931; Friesner & Potzger, 1932; Friesner, 1934).

2. *White Pine* is found on bluffs also, a few trees in one locality along Sugar Creek in Montgomery County, more along Pine Creek in Warren County and Bear Creek in Fountain County (Friesner, 1934). It is also frequently seen in the Indiana Dunes south of Lake Michigan (Lindsay, 1932).

3. *Tamarack* is found only in glacial bogs in northern Indiana, and has

Fig. 3. Ungrazed Beech Woods near Batesville, Franklin County, Indiana. U. S. Forest Service photo by B. S. Meyer. Summer, 1928.

never been found south of Allen County (Deam, 1921). A map of the peat deposits of Indiana could be used as a guide to many of the tamarack bogs.

4. *Arborvitae* grows in only one locality in Indiana, just south of a large sand dune at the "Mineral Springs" stop on the lake shore interurban line. It occurs here in association with white pine, tamarack, yellow birch, red maple and black gum.

5. *Shrubby Cinquefoil* covers a few small areas in northern Indiana, mostly in the marl bogs of the interlobate moraine of northeastern Indiana. Oddly enough, in these situations, tall grasses and other herbaceous species of the prairies are prominent members of the association.

Summary

The preliminary map of the major vegetation areas of Indiana gives a general picture of the natural vegetation of the state for the benefit of persons not well acquainted with the entire state. Eight major types or alliances of primary plant communities are recognized which are readily mappable by rapid reconnaissance. The eight major types can be further subdivided to include twenty-five or more primary plant associations and at least five relic associations which will be met with in the field. Detailed county surveys, similar to soil surveys, are urgently needed to reconstruct more accurately the original vegetation of the state. These will be of tremendous practical importance in land utilization and in wild life management projects.

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BF
MF
BSG
SSF
BC
Drawn by
R.B.GORDON
FEB. 1936

PG—Prairie grassland: Wet, mesophytic, and dry prairies.

OF—Upland oak forest: oak-hickory, oak-hickory-sugar maple, and white oak-yellow poplar types.

NSF—Phases of the northern swamp forest.

BF—Beech forest: pure stands of beech, beech-sugar maple and beech-sugar maple-yellow poplar types.

MF—Mixed forest area: oak-hickory on uplands, beech-sugar maple and beech-sugar maple-yellow poplar types, segregates of the mixed mesophytic forest.

BSG—Beech-sweet gum forests of "The Flats."

SSF—Phases of the southern swamp forest.

BC—Bald cypress forest of the lower Wabash Valley.

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A New Coral from the Olentangy Shale of Ontario

Grace Anne Stewart

Through the kindness of Irving G. Reimann, curator of geology, Buffalo Museum of Science, the writer has been able to study a new species of tetracoral from the Oletangy shale of Ontario, belonging to a genus which is represented by only four or five known species in the Devonian of North America. This genus, *Homalophyllum*, was erected by Simpson[1] in 1900 for Zaphrentoid tetracorals in which the corallum is flattened on the side of the greatest cruvature. As a result of this flattening the shape of the corallum becomes slipper-like, and Grove[2] later suggested that the term "calceoloid corals" (Latin *calceolus*—a little shoe) be used for this type of coral. As genotype Simpson selected *Zaphrentis ungula* Rominger from the Onondaga limestone. He pointed out that in the flattened corallum these corals resemble the genus *Calceola*, but did not mention the additional important fact that they lacked the operculum characteristic of *Calceola* and allied genera.

In 1935 Grove[3] emended the definition and distinguished two groups of the calceoloid corals. In one group, exemplified by *Calceola attenuata* Lyon, an operculum is present and the flattening is on the counter side. In the other, exemplified by *H. ungula* Rominger, there is no operculum and the flattening is on the cardinal side. *H. thedfordensis* falls in the second group.

Flattening of the corallum in the operculate corals has been the subject of much speculation. Richter has suggested that the flattened side of the corallum in the operculate corals was developed because of the necessity of a straight hinge for the articulation of the operculum, but this argument can not be advanced for the non-operculate calceoloids. It seems more likely that in this group flattening of the corallum is a direct result of adaptation to environmental necessity: that of having the calyx in an upright position. That this is the case with *H. thedfordensis* seems clear. That both groups had their origin in a common ancestral type, i.e. *Halophragma* of the Silurian (Grove), seems a reasonable supposition.

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1 Simpson, G. B., Preliminary Descriptions of New Genera of Paleozoic Rugose Corals, New York State Mus. Bull. **8**(39):221, 1900.

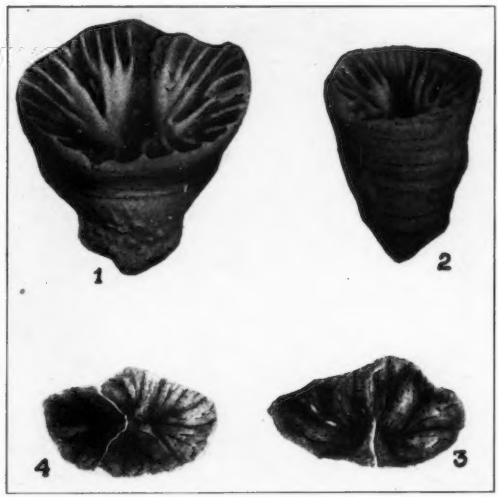
2 Grove, B. H., A. Revision of Some Mississippian Zaphrentids, Amer. Midl. Nat. **16**(3):356, 1935.

3 Op. cit., p. 353.

Family *Zaphrentidae* Milne-Edwards and Haime
Genus *Homalophyllum* Simpson (emend. Grove)
Homalophyllum thedfordensis sp. nov.

Figs. 1-4.

General Description:—Corallum small, calceoloid, flattened throughout the entire cardinal side, along which it was attached; expanding more or less regularly from a small pointed apex. Epithecal surface rugose, marked by irregularly-spaced growth wrinkles and undulations upon which are superimposed finer concentric ridges; costae variably visible on all specimens examined. Dimensions of the largest specimen: length of cardinal side 18 mm., length of counter side 9 mm., height of calyx 11 mm., width of calyx 16 mm. A second specimen has the following dimensions: length of cardinal side 15 mm., length of counter side 10 mm., height of calyx 6 mm., width of calyx 10 mm.



FIGS. 1-4. *Homalophyllum thedfordensis* sp. nov.

(1.) Calicular view of holotype, showing septal arrangement and deep fossula. x 2. (2.) View of a more slender specimen than holotype. Paratype, x 2. (3.) Serial section showing neanic stage. Paratype. x 6. (4.) Serial section of another individual showing ephebic stage. Paratype, x 6.

Calyx very shallow, oval in outline, oblique to such an extent that it is virtually in the plane of the long axis of the coral. Cardinal fossula deep and wide, situated symmetrically in the middle of the cardinal side. In most specimens the septa are grouped in such a manner as to leave a gap between alar and adjoining septa thus creating the illusion of alar fossulae. Cardinal septum entirely recessive or represented by a low septal ridge in the upper part of the fossula. Fig. 2 illustrates a specimen which has five low septal

ridges in the fossula, three of which extend about halfway to the center, while two are somewhat shorter.

Septa, in specimens examined, range from 17 to 27 in number. A few are evidently secondary, but because of stereoplasmic thickening it is not always possible to tell whether or not they unite with longer septa before the center is reached. Stereoplasmic thickening of the cardinal septa is especially noteworthy in Fig. 1.

The primitive quadripartite arrangement of the septa is particularly outstanding, those of the cardinal quadrants fusing into the fossular wall, and those of the counter quadrants extending to the alar septa. The counter septum appears not to be differentiated from the other septa of the counter quadrants. In two specimens there is the suggestion of its partial abortion. In the specimen of Fig. 1, the counter septum curves around to join the right alar septum in the bottom of the calyx.

Internal characters:—Extreme flattening and distortion of all specimens examined makes it difficult to obtain satisfactory serial sections for any one individual, but cross sections of several give a fairly good idea of the progressive growth stages. The neanic stage (Fig. 3), shows 9 strongly developed primary septa, a few of which are slightly undulatory, and three secondary septa, all the latter being in cardinal quadrants. The cardinal septum is beginning to recede from the center, and the counter septum is scarcely visible, although close inspection shows it to be present. In a late ephebic stage of another individual (Fig. 4) the number of septa is 15 or more, some being much more strongly developed than others. The cardinal septum, although less strongly defined than most primary septa, is still conspicuous, and scarcely more recessive than in the neanic stage of the individual of Fig. 3. Coalescence of the septa outlining the fossula with an adjoining septum in each of the cardinal quadrants forms a loop-like pattern in each quadrant, constant at all stages of development so far they have been observed. Secondary septa seem to be present during the ephebic stage although their number is variable. Neither tabulae nor dissepiments have been observed.

Remarks:—Aside from the flattening of the corallum on the cardinal side this species bears little resemblance to the others of the genus. The calyx is much shallower and more oblique, the septa fewer in number and more widely spaced. Most striking of all is the distinct quadripartite arrangement of the septa within the calyx. These differences may require separation of this species under a new genus when additional morphological studies are made. Material at hand does not justify this, however.

Horizon and Locality:—Olentangy shale, tile yard at Thedford, Ontario.

Holotype and Paratypes (3):—Catalogue no. 17996, Geological Museum, Ohio State University.

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